# SURGERY OF STOMACH AND SMALL INTESTINE

J. SHELTON HORSLEY

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SURGICAL MONOGRAPHS

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IS RESPECTFULLY AND AFFECTIONATELY DEDICATED

# PREFACE

Perhaps the large amount of space devoted to physiology of the gastro-intestinal tract in this monograph requires some explanation. It is obvious that the physiology of an organ or viscus cannot be comprehended without consideration of its embryology and its gross and histologic anatomy. The embryology also explains many deformities and conditions which result from defective development and which could not otherwise be understood. Meckel's diverticulum and congenital diaphragmatic hernias, the non-rotation of the cecum, accessory pancreatic tissue on the small bowel are not intelligible without a knowledge of the embryologic development of the abdominal viscera.

The physiology of the gastro-intestinal tract embraces three distinct functions—the chemical function of digestion, the function of absorption, and the motor function. Without a knowledge of the normal workings of the stomach and small intestine, attempts at removing disease and remedying defects of these organs must be to some extent gropings in the dark. Many recent investigations by physiologists show that some of the operative procedures on the stomach and small intestine have no really sound foundation. The true ideals of an operation are to remove or correct the pathologic conditions and to restore as far as possible the physiologic function. Without accurate acquaintance with physiology, surely function cannot be satisfactorily dealt with. It is in the cases in which the pathology is not advanced that a knowledge of the physiology of the gastro-intestinal tract is most serviceable, because here the opportunities for restoring function are greatest. Studies by Cannon and by Alvarez of the movements of the small intestine, particularly the difference in the motor function of the upper and the lower small bowel, have a very strong bearing upon the practical problems of intestinal operations. An understanding of the nature of the gastro-intestinal contents at different segments of the tract is helpful in pointing out the technic that should be adopted, because when the bacterial contents are small, opening of the lumen may be done with relative safety, but when the bacteria are abundant, exposure of the lumen should be avoided.

The work of Dragstedt in creating experimental peptic ulcers gives a strong indication to avoid trauma to the pyloric mucosa. Carlson and his associates have shown the comparative unimportance of the gastric juice in digestion, and the probable fallacy of the gastrin of Edkins—and the assumption of the presence of this hormone has been one of the arguments for pylorectomy. The work on peristalsis of the stomach as developed by Luckhardt, Wheelon, Cole, and others indicates the nature of gastric peristalsis and consequently the technic that should be followed in resection of the stomach, particularly in the right half where there are active peristaltic waves as compared with the left half where the contraction is tonic.

It is difficult to see how a surgeon can be content to adopt operative procedures in such complicated organs as the gastro-intestinal tract without seeing that they match up satisfactorily with modern physiologic research. Unless such operations are based upon the established facts of physiology they cannot in the long run endure.

An effort has been made to base operations and procedures as far as possible on biologic principles, and only those which seem to have such a foundation have been adopted.

In the chapters on intestinal obstruction the very important recent work of Foster and Hausler and of Haden and Orr has been emphasized.

I have received valuable assistance from Dr. H. E. Jordan, Professor of Embryology and Histology at the University of Virginia, in the preparation of the chapter on embryology. Dr. W. H. Higgins, head of the Medical Department of St. Elizabeth's Hospital, has kindly written the chapter on diagnosis of diseases of the stomach and small intestine. Dr. Fred M. Hodges, roentgenologist to St. Elizabeth's Hospital, has been good enough to furnish many roentgenographic illustrations showing the late results of some of the cases of resection of the stomach. Thanks are due to Miss Helen Lorraine for the illustrations in this volume. Added to her skill there has been an abiding interest devoted to the work placed in her hands that deserves especial recognition.

A brief bibliography is placed at the end of each chapter. It is not intended to make this complete; only the principal articles or books consulted are given. It seems useless to add an unnecessarily long list when in these days of accumulative indices all references can be easily found.

J. Shelton Horsley

Richmond, Virginia.

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## CHAPTER I

### EMBRYOLOGY OF THE STOMACH AND SMALL INTESTINE

Before considering abnormalities in structure and function of the stomach and small intestine, it may be well to review the embryology, anatomy, and physiology of these viscera.

The stomach first appears as a laterally flattened fusiform enlargement of the foregut in embryos 4 to 5 mm. in length. It arises just caudad to the primordium of the lungs and at a short distance cephalad to the yolk stalk. As the gastric enlargement descends the digestive tube above it is elongated, forming the esophagus. The epithelium of the stomach is thicker than that of the esophagus. Both are surrounded by splanchnic mesoderm. This early stage of the stomach appears about the fourth week. A short distance caudad to the primitive stomach the foregut opens freely into the yolk sac. The opening, which is at first wide, is gradually narrowed into a small tube called the yolk stalk or vitelline duct.

The allantoic duct arises from the digestive tube near its caudal end, which is then blind. About this time, in embryos measuring 2 to 3 mm., the primordium of the liver springs ventrally from the intestine just distal to the stomach, a portion of the digestive tube that later forms the duodenum. The liver grows rapidly. The pancreas develops in embryos of 3 to 4 mm. from two primordia, one arising ventrally from the precursor of the common bile duct, and one dorsally from the duodenum. The whole digestive tube, including the stomach, is attached dorsally by a band of mesoderm to the body wall along the midline, and it is from this band that the common dorsal mesentery of the intestine is subsequently developed. The stomach is attached to the ventral abdominal wall by a ventral mesentery which reaches down to the umbilicus. The liver grows into the ventral mesentery, subsequently spreading into the caudal portion of the septum transversum. That portion of the ventral mesentery lying between the liver and the stomach is the lesser omentum, or gastrohepatic ligament. As development proceeds the stomach dilates locally to form the fundus, and subsequent unequal growth between the ventral and dorsal borders produces the dorsal greater curvature. At this period of development the two surfaces of the stomach face right and left (Fig. 1). The intestine becomes greatly elongated and forms a V-shaped loop pointing downward and forward. From the apex of this

loop the vitelline duct passes to the navel and for a time a portion of the loop extends into the celom of the umbilical cord. Towards the end of the third month, however, the loop of intestine is withdrawn within the abdominal cavity. As the intestinal tube is lengthened, the attachment of mesoderm

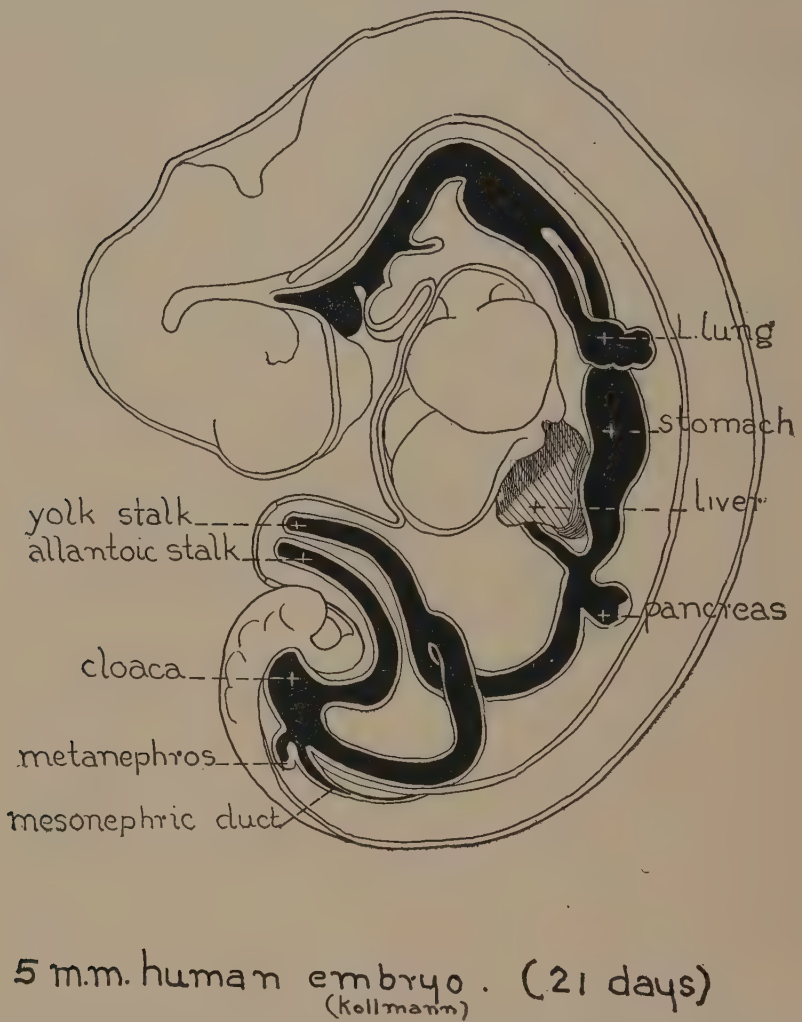


FIG. 1.—RECONSTRUCTION OF A 5 MM. HUMAN EMBRYO 21 DAYS OLD, SHOWING THE ENTODERMAL CANAL AND ITS DERIVATIVES. (His, from Kollmann.) (X 25)

dorsally becomes drawn out, forming the dorsal common mesentery. The part of this mesentery along the greater curvature of the stomach, which lies dorsally at this stage, is called the dorsal mesogastrium, while the portion which suspends the colon is named the mesocolon. In the sixth week there appears just behind the opening of the vitelline duct a diverticulum in the gut from which arise the cecum and vermiform appendix, while that part of the loop distal to the diverticulum increases and forms the ascending and trans-

verse colon (Fig. 2). The cecal diverticulum has a uniform diameter until about the fifth month of fetal life, after which time its distal portion remains rudimentary and forms the vermiform appendix, while the proximal portion expands to form the cecum. The spleen develops on the left border of the dorsal mesogastrium essentially as an aggregation of lymphocytes. Defini-

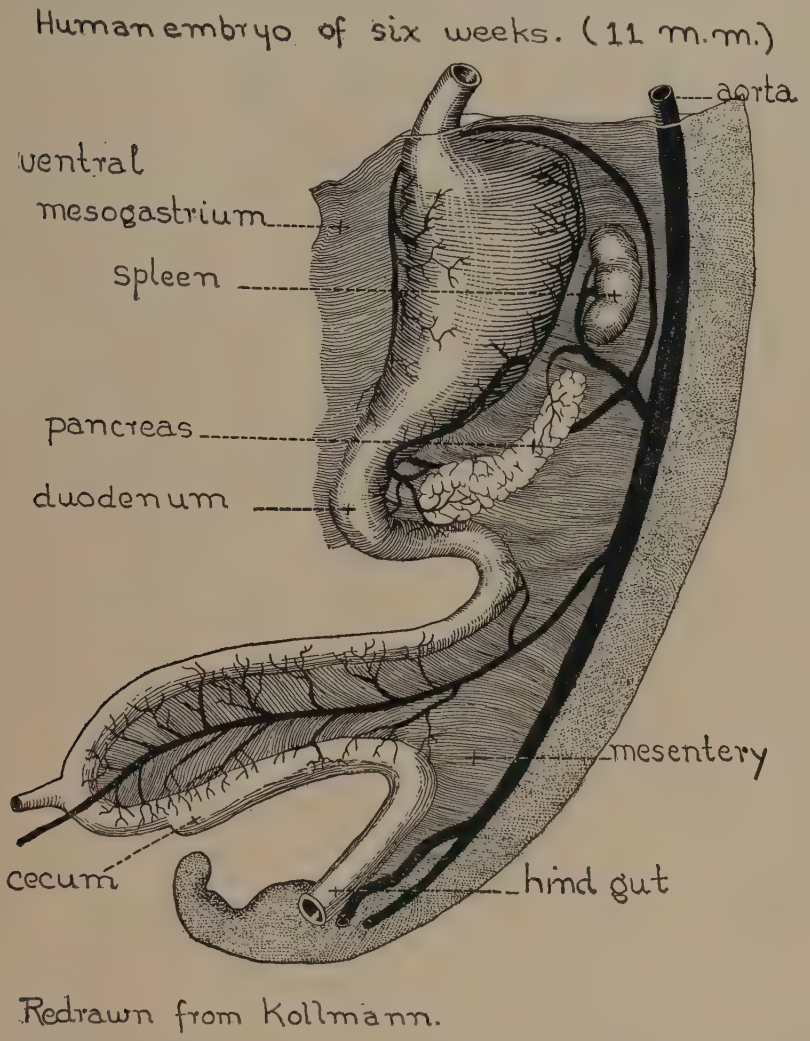


FIG. 2.—THE DIGESTIVE TUBE AND ITS ATTACHMENT TO THE PRIMITIVE OR COMMON MESENTERY IN A HUMAN EMBRYO OF SIX WEEKS. (After Toldt.)

tively its mesenteric origin is indicated by the connecting gastrosplenic ligament.

The dorsal or the greater curvature of the stomach, to which is attached the dorsal mesogastrium, develops much more rapidly than the ventral border to which the ventral mesogastrium is attached. This rapid development of the greater curvature gives the characteristic appearance of the stomach, and partly as a result of this development, and partly probably because of the

growth of the liver, the stomach rotates so that the right surface of the stomach becomes directed dorsally and the left surface ventrally. Naturally, as the stomach rotates, the vagus nerves are carried along with the stomach so that the left vagus nerve is carried to the ventral surface of the stomach and the right to the dorsal surface. The dorsal mesogastrium along the greater curvature must, of course, follow the movements of the stomach. It becomes much elongated and forms a wide pouch behind the stomach. The right surfaces of both the dorsal and ventral mesogastria are changed with the movement of the stomach so that they are directed backward, and the left surfaces of the mesogastria face forward. In this manner the bursa omentalis or lesser peritoneal sac is formed behind the stomach. The bursa omentalis grows in size as the digestive tube develops and becomes a closed sac with the exception of the foramen epiploicum, or the foramen of Winslow.

The duodenum springs from that part of the intestinal tube immediately caudal to the stomach. It elongates but slightly because it is more or less fixed in position by the liver and by the pancreas, which, it has been explained, arise from the duodenum from diverticula, the liver coming from the anterior surface and the pancreas by a double origin from the posterior surface and from an evagination from the liver diverticulum. At first the duodenum is suspended by a mesentery and has the form of a loop. This loop with its attached mesentery is later displaced by the transverse colon, which causes the right surface of the mesentery of the duodenum to be directed dorsally. This surface becomes adherent to the dorsal parietal peritoneum and is obliterated.

The remaining part of the digestive tube becomes much elongated and is coiled on itself. There results in consequence an expansion of the attached mesentery which becomes folded in a fan-shaped manner. At this time the intestines, large and small, are attached to the dorsal body wall by a common mesentery, the small intestine falling to the right of the midline and the large intestine to the left.

In the next stage of development rotation of the gut begins and the colon passes over in front of the small intestine until the cecum is immediately below the liver on the right side. During the sixth month the cecum descends into the right iliac fossa, while the large intestine becomes elongated and the ascending, transverse, and descending colon are recognized. The transverse colon passes in front of the duodenum and just below the greater curvature of the stomach. Not infrequently the rotation of the cecum is incomplete, and it rests below the right portion of the liver.

The proximal part of the yolk stalk, or vitelline duct, normally disappears during fetal life. When it persists it forms a blind sac of variable length, known as Meckel's diverticulum.

The primitive digestive tube consists of an entodermal epithelial lining enveloped by a layer of mesenchyme. The latter, except in the esophagus, is clothed with visceral mesothelium. According to Carey, the epithelial tube grows in a left-handed helicoidal direction, thus creating a corresponding mesenchymal vortex. This imposes a spiral structure upon the

tela submucosa and the tunica muscularis as they differentiate from out of the primitive mesenchyme. The submucosa differentiates as an inner close and an outer elongated spiral of connective tissue fibrils. The inner spiral is said to make one complete turn in every 0.5 to 1 mm. or less, the outer in every 4 to 10 mm. Likewise the tunica muscularis becomes arranged into an inner continuous muscular sheet wound into a close helix, complete turns of which range from 0.5 to 1 mm. length, and an outer layer of elongated spiral fibers, complete turns of which range from 200 to 500 mm. (7.85 to 19.75 inches).

Histogenesis of the extra-epithelial layers appears to be the result of the formative interaction of differential growth between the competitive accelerated growth of the entodermal tube and the retarded growth of the surrounding mesenchyme. The plicæ circulares of the small intestine become arranged as interdigitating spirals. These structural conditions, particularly of the tunica muscularis, that is, the left-handed helicoidal arrangement of the constituent fibers, determine a left-handed screw-like action of intestinal movements. Peristalsis finds its explanation in the reciprocal elongating action of the outer and inner layers of muscle respectively. The inner "circular" muscle layer becomes discernible at about the sixth week, the outer "longitudinal" layer at about the twelfth week.

Early in the second month the esophagus is lined by a double layer of columnar cells. At birth the lining consists of approximately ten layers of cells constituting a stratified squamous epithelium. During the second month the lumen is almost obliterated, but by the eighth week numerous vacuoles appear among the epithelial cells, thus helping to enlarge the lumen. Persistence or exaggeration of the normal constricted condition of the embryonic esophageal lumen produces congenital esophageal stenosis or atresia. Esophageal glands begin to develop during the fourth month. According to Johnson, the esophagus in fetuses ranging from 55 mm. (2.2 inches) to full term are characterized by occasional areas of ciliated epithelium. The anomaly of islands of ciliated epithelium in the definitive esophagus finds its explanation in the persistence of these embryonic patches.

The primitive entodermal lining of the gastric region differentiates into the simple columnar epithelium of the definitive stomach. Gastric glands become discernible as pits by the middle of the second month. They begin to differentiate towards the end of the fourth month, and may increase their number in part by fission.

Villi characterize both the small and large intestine during early fetal life. They make their appearance early in the third month, but suffer obliteration throughout the colon and rectum during the eighth month. The intestinal glands (crypts of Lieberkühn) begin to develop early in the fourth month. The duodenum is especially liable to atresia.

The bursa omentalis at first reaches only to the greater curvature of the stomach. Later it grows downward and forms the great omentum, passing in front of the transverse colon and the small intestines. The bursa omentalis sends two diverticula upward before the pleuroperitoneal opening is closed. They reach up on each side of the esophagus; on the left side the diverticulum

soon disappears, but on the right side it is constricted and may be found in most adults as a small sac (the infracardiac bursa) within the mediastinum to the right of the lower end of the esophagus. The ventral surface of the transverse mesocolon is at first not attached to the dorsal layer of the great omentum, but later these two surfaces blend so that the great omentum appears to be attached to the transverse colon. The mesenteries of the ascending and descending colon usually disappear.

The lesser omentum is formed by thinning out of the ventral mesogastrium, which originally attached the stomach and duodenum to the anterior abdominal wall. The rapid growth of the liver into this ventral mesogastrium divides this leaf of the mesoderm into two parts, one of which constitutes the lesser omentum between the stomach and the liver, and the other the falsiform and coronary ligaments which attach the liver to the abdominal wall and diaphragm.

A consideration of the embryology of the stomach and small intestines renders comprehensible many of the pathologic conditions in these viscera as being a departure from normal embryologic development. Thus the etiology of Meckel's diverticulum, the presence of the terminal ileum, cecum, and appendix under the right lobe of the liver, ptosis of the transverse colon from nonadherence to the great omentum, and diaphragmatic hernia to the right or to the left of the esophagus, can be readily understood.

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## CHAPTER II

## ANATOMY OF THE STOMACH AND SMALL INTESTINE

### THE STOMACH

The stomach is the dilated portion of the digestive tube which is situated between the termination of the esophagus and the beginning of the small intestine. Its shape and position are greatly modified by its contents and by the surrounding viscera, so a typical description cannot be given. The stomach has two openings, two borders or curvatures, and two surfaces. The cardiac orifice communicates with the esophagus and the pyloric with the duodenum. A short portion of the esophagus, called the cardiac antrum, is conical in shape and curves sharply to the left. The base of this cone is continuous with the cardiac orifice of the stomach. The right margin of the orifice is continuous with the lesser curvature of the stomach. The upper border, or lesser curvature, extends between the cardiac and pyloric orifices and in the original state was anterior, as explained in the preceding chapter. Near its pyloric end there is a rather well marked notch, called the incisura angularis. This varies with the position and distention of the stomach, but is used as an anatomical landmark to divide the stomach into two portions, the right and the left. The gastro-hepatic ligament, or omentum, is attached to the lesser curvature, and between the two layers of this omentum are the left gastric artery and the right gastric branch of the hepatic artery. The greater curvature is chiefly forward and is four or five times longer than the lesser curvature. Beginning at the cardiac orifice it arches backward and upward to the left and then downward and forward, and turning to the right ends at the pylorus.

Opposite the incisura angularis there is a dilatation on the greater curvature to the right of which is a slight groove. The portion of the stomach between this groove, which is called the sulcus intermedias, and the duodenum is called the pyloric antrum (Fig. 3).

The outlines of the stomach are very changeable depending not only upon the individual, but upon the position of the body and most of all upon the quantity of contents in the stomach. For these reasons it is difficult for observers to fix upon definite anatomical divisions for the stomach. Probably the most satisfactory for practical purposes, both for diagnosis and from the standpoint of physiology, is the outline suggested by Cannon, or some slight modification of it. Accordingly, the stomach is divided into two main portions, the cardiac and pyloric. This division is indicated by the notch at the lesser curvature, the incisura angularis, which has been described. A line is drawn from this notch to a point about opposite it on the greater curvature. All of the stomach to the left side of this line is called the cardiac, and to the right the

pyloric, portion. The cardiac portion is again subdivided into the body of the stomach, or the pars media as it is sometimes termed, and the fundus. The fundus is that part above a line drawn horizontally through the cardiac orifice. Between the fundus and the incisura angularis is the body, or the pars media. The pyloric division of the stomach lies to the right of the incisura angularis and is divided by some observers into three parts and by others into two. The pyloric canal is that portion of the stomach about 3 cm. (1.2 inches) long, which terminates in the pyloric sphincter. The rest of the pyloric division from the pyloric canal to the incisura angularis is called the antrum of the stomach. Sometimes this latter region is subdivided into the antrum and the vestibule, which seems unnecessarily complicated. According to such an arrangement the vestibule is the first subdivision of the pyloric portion, beginning at the incisura angularis, while the antrum would lie between the vestibule and the pyloric canal.

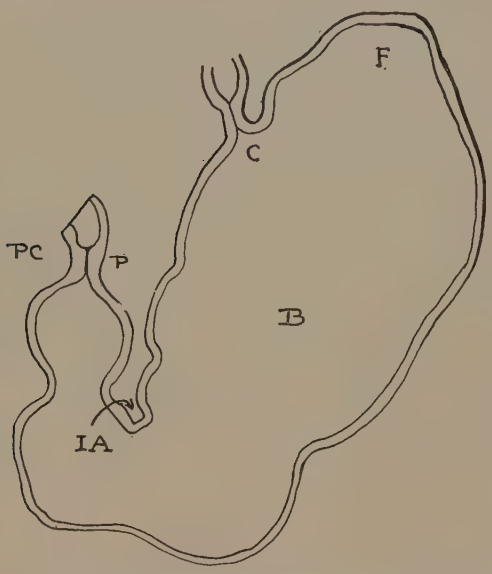


FIG. 3.—SCHEMATIC OUTLINE OF THE STOMACH. C, cardia; F, fundus; IA, incisura angularis; B, body; PC, pyloric canal; P, pylorus. The antrum is the portion from IA to PC, inclusive. (From Cannon.)

The pyloric canal is about 3 cm. in length and very muscular.

Externally the stomach is completely covered by peritoneum except for two narrow strips along the curvatures. Beneath the peritoneum is the muscular coat, which is divided into three layers. The outer layer is of longitudinal muscle fibers, a continuation of the external longitudinal muscular coat of the esophagus. This coat forms a narrow and powerful band of muscle fibers along the lesser curvature, and a broader but feebler band along the greater curvature. The bundle along the lesser curvature spreads out somewhat in the pyloric region, and becomes thinner at this point. The first of the two sets of longitudinal muscle fibers is practically lost when the pyloric portion of the stomach is reached, except along the lesser curvature where some of the fibers pass over the pylorus and on to the duodenum. The second set of longitudinal fibers begins on the body of the stomach and passes over the pylorus, the deeper fibers dipping inward and interlacing with the circular fibers of the pyloric sphincter (Fig. 4). The second layer is the circular muscular coat, which is arranged in circular bands covering the whole stomach with the possible exception of the fundus. This layer is directly connected with the circular muscular coat of the esophagus and also of the duodenum. At the pylorus it is particularly powerful and serves to form the aggregation of circular muscles which constitutes the pyloric sphincter. The

circular fibers of the stomach connect with the circular fibers of the duodenum, though the transition is quite sudden and the circular fibers of the duodenum are much less powerful than those of the pylorus. The deepest layer of muscle is the oblique layer. This is connected at the left side of the cardia with the circular muscle fibers of the esophagus. The fibers of this oblique layer diverge upon the anterior and posterior surfaces of the stomach. Along the lesser curvature they run more or less parallel and extend as far as the pyloric portion of the stomach. The lower fibers curve around the stomach obliquely and at the greater curvature take the general direction of the circular muscle fibers which they reinforce.

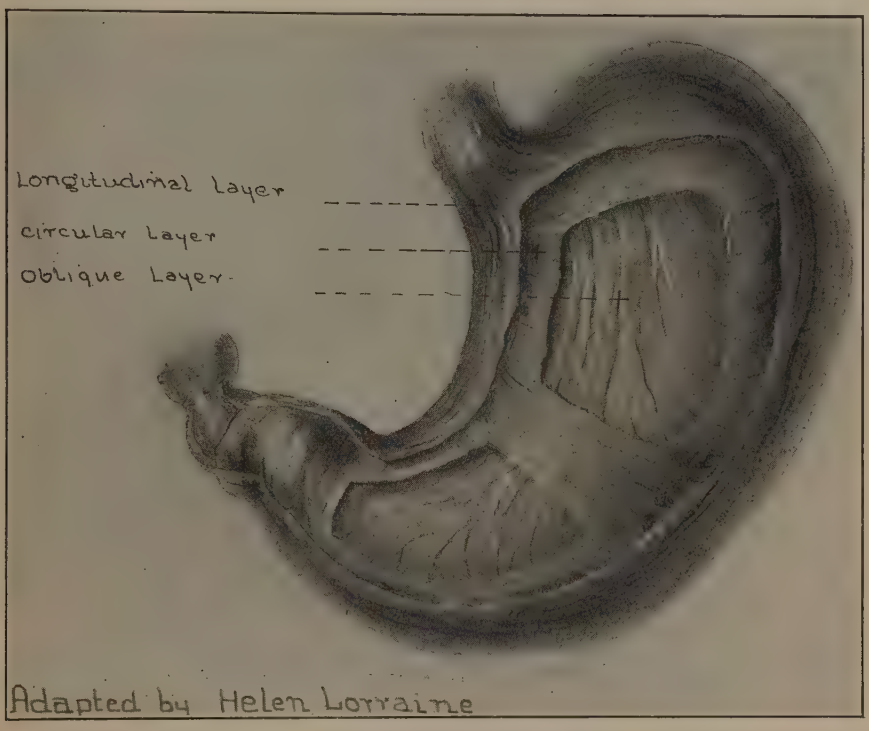


FIG. 4.—DRAWING SHOWING THE RELATION OF THE DIFFERENT MUSCULAR LAYERS OF THE STOMACH. (Adapted from Spalteholz.)

The mucous membrane of the stomach is separated from the muscular layer by the submucosa. The mucous membrane has a brownish-red color, which is of a more pinkish tinge in the pyloric region than in the cardiac portion. This contrasts very sharply with the light color of the mucous membrane of the esophagus. When the stomach is contracted the mucosa with the submucosa forms numerous folds, or rugæ. These are placed as an irregular network, except along the lesser curvature where there is a longitudinal groove. When the stomach is markedly distended these folds disappear. At the pylorus, however, there is always a circular fold which is shoved forward by the contraction of the sphincter of the pylorus. Aside

from these larger folds there are smaller elevations incompletely separated from each other. Over the entire mucous membrane of the stomach can be observed with a hand lens minute depressions, resembling a honeycomb appearance, which are roughly hexagonal in form. These depressions constitute the ducts of the gastric glands, and at the bottom of the depressions one or more minute orifices, which are openings of the gland tubes, may be observed. In the thin partition between these depressions are small flat villous processes which are more marked in the pyloric region.

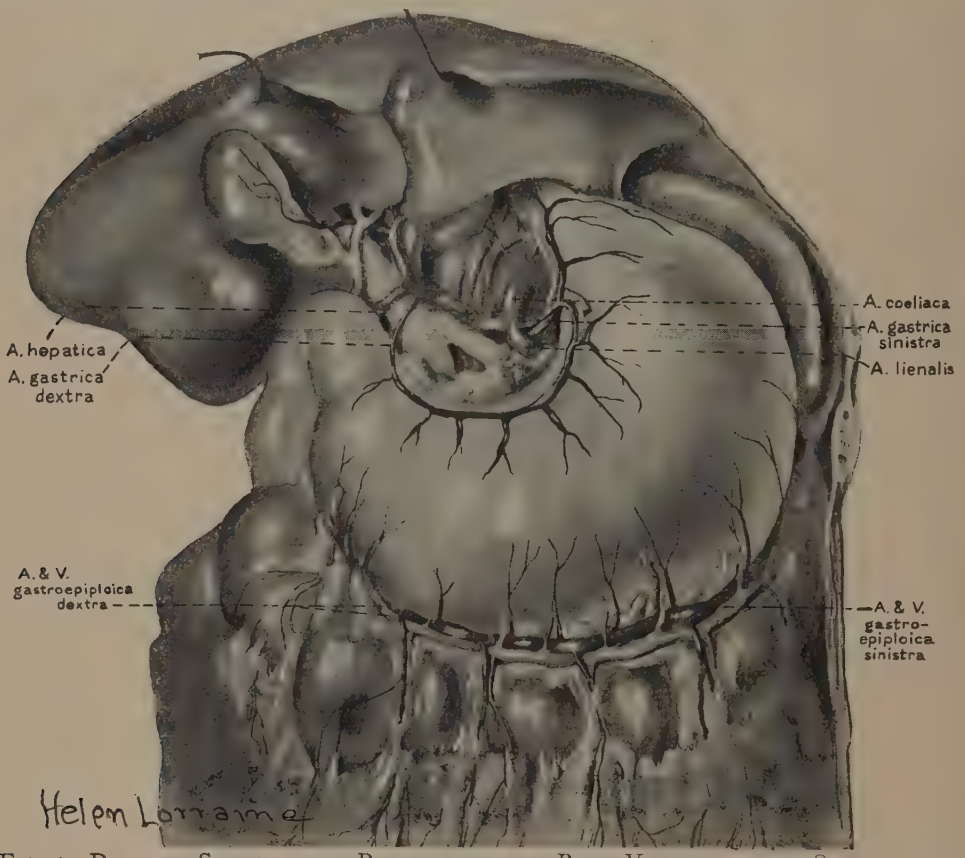


FIG. 5.—DRAWING SHOWING THE RELATION OF THE BLOOD-VESSELS TO THE STOMACH AND SURROUNDING TISSUES.

The various layers of the muscular coats of the stomach are united by thin partitions of connective tissue. The septum of connective tissue between the longitudinal and the circular muscular layers contains the myenteric nerve plexus (Auerbach's plexus) and the larger blood-vessels.

The submucosa consists of loose areolar tissue and supports blood-vessels and lymphatics and the submucous plexus of nerves (Meissner's plexus) which are distributed to the mucous membrane.

The arteries supplying the stomach are the left gastric from the aorta, the right gastric, and the right gastro-epiploic branches of the hepatic artery,

together with the left gastro-epiploic and the short gastric arteries of the lienal or splenic artery. These branches supply the various structures of the stomach, ramify in the submucous coat, and after considerable anastomoses distribute branches to the mucous membrane. The main trunks run along the greater and lesser curvatures, and after giving branches to the intermuscular septa and to the capillary plexus within the muscles, the vessels spread out in the submucosa where they form an extensive arterial plexus. From this submucous plexus branches penetrate the mucous membrane and give rise to a dense capillary plexus whose meshes inclose the secreting gastric glands. The veins pursue a course between the tubules to the submucosa, and empty into the lienal or splenic vein, then into the superior mesenteric vein or sometimes directly into the portal vein. The veins also form a venous plexus during the course of the return flow of blood. The lymphatics arise by loops or as dilated extremities between the gastric glands of the mucosa. They form near the base of the mucous membrane and their delicate plexus anastomoses freely. From this plexus branches penetrate the muscularis mucosæ and enter a broad submucous plexus from which vessels penetrate the muscular coat on their way to the lymph nodes in the folds of the omentum along the greater or lesser curvatures of the stomach (Fig. 5).

The nerve supply of the stomach is derived from the vagi and from the sympathetic through the splanchnic nerves. They enter along with the blood-vessels and penetrate the muscular coat. As has been pointed out in the chapter on embryology, on account of the rotation of the stomach the left vagus supplies the anterior wall of the stomach and the right vagus the posterior wall. The nerves from the vagus and the sympathetic form two plexuses of nerve trunks, the myenteric (Auerbach's), which is situated between the longitudinal and circular fibers of the muscular coats, and the superficial, or submucous (Meissner's) plexus which lies in the deeper part of the submucous coat. Both of these plexuses seem to contain ganglionic enlargements and small ganglia at many of the intersections of their anastomosing branches. The submucous (Meissner's) plexus is finer and is made up of much smaller fibrils than the Auerbach plexus. The submucous plexus sends to the mucosa fibrils which terminate in and around the walls of the blood and lymph vessels, and also minute branches to the epithelium of the secreting glands where they end as varicose fibrils upon the cells.

The mucous membrane rests upon the submucosa. The deepest layer of the mucosa is the muscularis mucosæ, which forms a thin though complete layer from one end of the stomach to the other. The muscularis mucosæ is composed of two layers, an inner or circular layer and an outer or longitudinal layer.

Occasional muscle fibers extend from the muscularis mucosæ into the corium, or supporting connective tissue structure in which the gastric glands are held. Superficially the mucosa is lined with tall columnar epithelium, and when the stomach is emptied the whole mucosa is thrown into folds, or waves, which is possible because of the very loose structure of the submucosa. The corium of the mucosa contains the closely packed tubular secreting glands that

open by wide-mouthed, crypt-like ducts or foveolæ. Surrounding these glands is a fine fibroreticular tissue normally containing many lymphocytes.

The histology of the gastric glands varies in the different portions of the stomach. They are usually classified as fundic, cardiac, and pyloric glands. The fundic glands are tubular glands, somewhat branched, and terminate in short ducts or crypts. They have a relatively long secreting portion. Several of these glands open, by a short constricted portion called the neck of the glands, into the bottom of these wide ducts or crypts. These wide ducts are lined with tall columnar epithelial cells, having very clear cytoplasm with the nuclei at the base of the cells. These columnar epithelial cells rest on a basement membrane of reticular tissue which is continued over a part of the corium in the interval between the adjacent ducts. It is this epithelium that forms the lining of the mucosa of the stomach. From these cells is secreted a clear mucus-like fluid. The secreting portion, or fundus, of these glands is five to eight times as long as the duct, which is quite different from the fundus of the pyloric glands. The lumen of the secreting portion is very narrow.

The fundus of these glands contains two distinct kinds of cells, the chief cells and the parietal cells. The former are relatively much more abundant in the deeper portion of the fundus where the parietal cells are almost absent. Here the few parietal cells that exist are crowded away from the lumen toward the basement membrane. As the neck of the gland is approached the parietal cells are more abundant and come gradually nearer the lumen until in the very neck of the tubule of the gland the parietal cells have a considerable free surface on the lumen of the gland. The chief cells, sometimes called central or peptic cells, are cuboidal or pyramidal in shape, and contain a granular cytoplasm. The nucleus is spheroidal and is situated near the attached end of the cell. The distal portion of the cell is the most granular part. The amount of the granular zone depends upon the stage of glandular activity. The granules, which consist of zymogen, accumulate during rest and disappear largely during secretory activity. This zone of the distal granular area always increases during rest and decreases during secretion. After prolonged secretion the whole cell becomes shriveled, while it swells after periods of rest and may occlude the lumen. These zymogen granules within the cells are apparently suspended within the meshes of the cytoplasmic reticulum. At the bases of the cell elongated filaments of prozymogen can be demonstrated by proper stains. These prozymogen granules are arranged parallel to the axis of the cell. The chief cells are believed to secrete pepsinogen, which forms the pepsin of the gastric juice.

The parietal, or oxyntic, cells are large ovoid or pyramidal, and often contain two nuclei. The cytoplasm has a strong affinity to acid dyes. Their spherical nuclei are centrally situated and contain chromogen, while the cytoplasm is homogeneous or finely granular. The shape of these cells varies somewhat with their location. At the fundus of the gland where they are crowded out by chief cells and shoved toward the basement membrane, they are ovoid to triangular, with the broad base of the triangle resting on the basement membrane. In the middle portion of the tubule the parietal cells

come nearer to the lumen and as they are squeezed by the chief cells on each side they become taller. At the neck of the gland where they are numerous they present the broad surface to the lumen and are cuboidal in shape. As the tubule opens into its wide duct the parietal cells disappear abruptly.

Where the parietal cells are much removed from the lumen in the tubule they have a rather extensive system of secretory canals which surround the cells like a net, and carry this secretion to the lumen of the tubule. There are also intracellular canaliculi. The parietal cells are supposed to secrete the

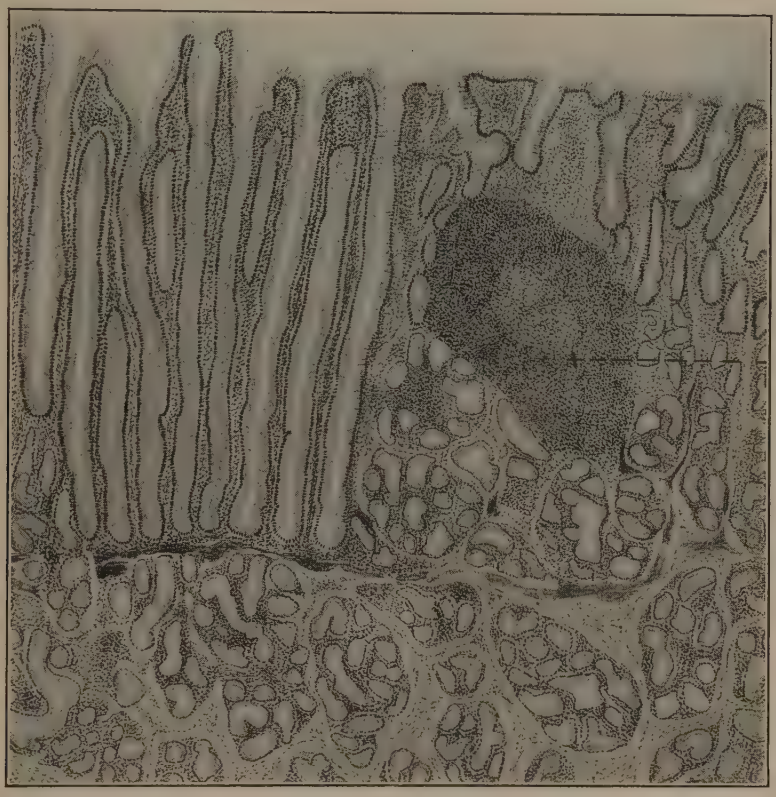


FIG. 6.—DRAWING SHOWING THE HISTOLOGIC STRUCTURE OF THE GLANDS AT THE END OF THE PYLORIC PORTION OF THE STOMACH AND THE BEGINNING OF THE DUODENUM.
Note that Brunner's glands not only occur in the submucosa of the duodenum but underlie the pyloric glands in this region. (X 41)

hydrochloric acid of the gastric juice. It is usually believed that they actually secrete chlorids which are converted into hydrochloric acid after the secretion reaches the crypts of the duct. This point, however, has not been definitely determined.

The pyloric glands are branched, convoluted tubular glands (Fig. 6). They have relatively long ducts which are crypt-like and into the bottom of these ducts several of the tubules open. The convolution appears in the fundus of the gland; the ducts are practically straight. The branching, however, is confined chiefly to the ducts which make up the superficial two-thirds

of the thickness of the mucous membrane. The pyloric mucosa consists of superficial, middle, and deep zones. The superficial zone contains the wide-mouthed crypts lined with tall, columnar cells like the crypts of the fundic glands. The middle zone consists of the narrow portion of the ducts and is the broadest of these three zones. Very narrow ducts open into each of the crypts, or foveolæ. The epithelium of the ducts is the low columnar type with spheroidal nuclei. The superficial cytoplasm often has a grossly granular appearance. The deepest zone contains the convoluted portion of the tubules which is the main secreting portion. This zone is sharply marked off from the adjacent ducts because in sections of the stomach wall the tubules are nearly all cut across due to their convolutions, while the ducts are in longitudinal sections. The tall columnar epithelium and the large lumen of the fundus is in strong contrast with the low granular epithelium and narrow lumen of the duct. This zone of markedly convoluted tubules lies just within the muscularis mucosæ which is one of the distinguishing marks from other regions of the digestive tract. The tall columnar cells of the fundus of these glands have a very clear cytoplasm which reacts to the stains for mucus. The nuclei rest against the base of the cells and are flat in contrast with the spheroidal nuclei of the ducts. These cells become shrunken during secretion when their nuclei approach the center of the cells and assume a somewhat spheroidal shape.

There is no sharp line between the regions of the fundus and the pylorus of the stomach, and there is a gradual transition from one type of gland to the other. Often the parietal cells are distributed throughout the entire gastric mucosa.

There is a narrow region around the cardiac orifice of the stomach in the human being which contains glands that correspond somewhat to the glands of the fundus. They are, however, slightly more branched, more tortuous, and are lined by rather clear columnar epithelium. Occasionally the chief and parietal cells are found among the clear cells of these tubules. The cardiac glands seem to be a stage of transition between the mucous esophageal glands and the fundic glands of the stomach, and occupy relatively an unimportant part in the human being.

The corium of the mucosa is a delicate fibroreticular connective tissue and supports the blood and lymph vessels. It is normally infiltrated to some extent with lymphocytes. In some portions of the stomach it seems to contain diffuse lymphoid tissue which appears chiefly in the deeper portions of the mucosa. In the deep parts occasional small lymph nodes are found. These lie just within the muscularis mucosæ and do not penetrate into the submucosa. They correspond to some extent to the solitary glands in the follicles of the intestine.

## THE SMALL INTESTINE

The embryology of the small intestine has been discussed in connection with the stomach. The small intestine begins at the termination of the

stomach and ends at the ileocecal valve. It has a gradual tendency to diminish in size from its beginning to its termination. The whole length of the small intestine is about 24 feet (7.32 m.). The small intestine is divided into three portions: the first, the duodenum; the second, the jejunum; and the third, the ileum.

**The Duodenum.**—The duodenum receives its name because it is supposed to be about equal to the breadth of twelve fingers. It is approximately 11 inches (28 cm.) in length. It has no mesentery and is partially covered by peritoneum. Its course is horseshoe shaped, and beginning at the pylorus passes backward and upward to the right near the neck of the gall-bladder, then curves sharply along the right border of the head of the pancreas, takes another marked bend passing obliquely from right to left across the vertebral column in an upward direction, and finally terminates on the left of the vertebral column about opposite the second lumbar vertebra where it becomes the jejunum. At this junction it turns forward very abruptly. These four different portions are called the superior, the descending, the horizontal, and the ascending portions.

The first portion is the most movable of the four portions and is almost completely covered by peritoneum. It is about two inches long (5 cm.).

The second, or descending, portion extends from the neck of the gall-bladder along the right side of the vertebral column to the upper border of the fourth lumbar vertebra, and is three to four inches (7.5 to 10 cm.) long. This portion is crossed by the transverse colon. The posterior surface of the descending portion of the duodenum is not covered by peritoneum. Anteriorly it is in relation in front with the right lobe of the liver, the transverse colon, and the small intestine. Behind it usually rests upon the fatty capsule at the front of the right kidney and in close relation posteriorly and below with the renal vessels and the inferior vena cava. Toward the midline it embraces the head of the pancreas and the common bile duct. The common bile duct with the pancreatic duct penetrate obliquely the median side of the wall of the second portion of the duodenum. Sometimes an accessory pancreatic duct (Santorini) enters it about an inch (2.5 cm.) above and slightly in front of the common bile duct and pancreatic duct. At the entrance of the common bile duct and the pancreatic duct into the lumen of the duodenum there is a marked protrusion. Frequently these two ducts practically fuse and enter as one duct, the pancreatic duct joining the common bile duct. The common bile duct lies to the right of the pancreatic duct, and the two pass obliquely to the duodenum. At the summit of this protrusion or papilla the two ducts unite and have a common orifice. It is situated on the median side of the wall of the descending portion of the duodenum, a little below its middle, about three to three and a half inches (7.5 to 9 cm.) from the pylorus. A short tube formed by the junction of the two ducts is often dilated and is called the ampulla of Vater.

The horizontal portion of the duodenum is about two to three inches (5 to 7 cm.) long, and begins on the right of the upper border of the fourth lumbar vertebra, passes from right to left with a slight upward direction, in

front of the great vessels of the abdomen, and ends in the ascending portion of the duodenum just in front of the abdominal aorta. The horizontal portion is crossed by the superior mesenteric vessels and the mesentery. It is covered in front by the peritoneum except where it is covered in the midline by the superior mesenteric vessels. There is no peritoneum posteriorly, except at the left extremity where sometimes a layer of mesentery is attached. The upper surface of the horizontal portion is in close relation with the pancreas.

The ascending portion, or the fourth portion, of the duodenum, is about an inch (2.5 cm.) long. All of the duodenum is moderately fixed except the first portion, which is somewhat movable. At the duodenojejunal flexure the bowel is fixed by a structure called the suspensory muscle of the duodenum. This begins in the connective tissue around the celiac artery, and the left crus of the diaphragm and, passing downward, is inserted into the upper border of the duodenojejunal curve and part of the ascending duodenum. From this point it is continued into the mesentery.

The vascular supply of the duodenum is the right gastric and the superior pancreaticoduodenal branches of the hepatic, and the inferior pancreaticoduodenal branches of the superior mesenteric. The veins end in the lienal or the splenic vein, and the superior mesenteric.

The nerve supply is from the celiac axis and a continuation of the plexuses as in the stomach, which give connection from the vagus as well as from the sympathetic.

**The Jejunum and the Ileum.**—The rest of the small intestine is arbitrarily divided into the jejunum and the ileum. The jejunum comprises the upper two-fifths of the rest of the small bowel, and the ileum the lower three-fifths. There is no distinct boundary line between these two divisions, and the general character of the intestine changes from the beginning of the jejunum to the termination of the ileum.

The jejunum, which is about 9 feet (2.75 m.) in length, is derived from the Latin word meaning empty or hungry, for in postmortem examinations it rarely contains food. There are numerous convolutions. The caliber of the jejunum is about 1.6 inches (4 cm.). The intestine gradually narrows until in the ileum the diameter is 1.5 inches (3.75 cm.). The ileum is about 14 feet (4.27 m.) in length, and is distinctly of thinner coat and less vascular than the jejunum.

The jejunum and ileum are attached to the posterior abdominal wall by the folds of the peritoneum which constitute the mesentery and which allow very free motion, so that the coils can adapt themselves to different positions. The mesentery is fan-shaped, and its posterior border, or root, is about 6 inches (15.3 cm.) long and is attached from the left side of the body of the second lumbar vertebra to the right sacro-iliac articulation. This attachment is oblique from above downward and to the right, and crosses the horizontal part of the duodenum, the aorta, the inferior vena cava, the right ureter, and the right psoas muscle. It is broader in the middle than at either end. Between the layers of mesentery are blood-vessels, nerves, lymphatics, and lymph nodes, together with a considerable amount of fat.

In about 2 per cent of all persons there is a projection at the lower part of the ileum called Meckel's diverticulum. It is usually found about 3½ feet (107 cm.) from the ileocecal valve, and its average length is 2 inches (5 cm.). Its caliber is usually the same as that of the ileum from which it springs. The blind end may be entirely free, or may be connected with the abdominal wall or with some loop of intestine by a fibrous band. This diverticulum is the remains of the proximal portion of the vitelline duct which in early fetal life communicates between the yolk sac and the primitive digestive tube.

The jejunum and ileum are both supplied by the superior mesenteric artery. The branches of this artery reach the attached border of the bowel by running between the layers of the mesentery. There are frequent inosculations, forming arches. From the terminal arches branches are finally given off which penetrate the muscular coat of the bowel, and make an extensive plexus in the submucous coat. From this plexus vessels pass to the glands and the villi of the mucous membrane. The veins return in a similar manner.

The lymphatics, or lacteals, of the small intestine are in two sets, one of the mucous membrane, and the other of the muscular coat of the intestine. They form an intricate plexus in the mucous membrane, and in the submucosa, which is joined by the lymphatics from the lymph spaces around the solitary nodules. These lymphatics empty into the larger lymph vessels at the mesenteric border of the intestine. The lymphatics of the muscular layers are largely between the circular and the longitudinal coats, and form a plexus. They communicate freely with the lymphatics from the mucous membrane and drain into the common lymphatic trunks along the attached border of the intestine.

The lumen of the small intestine changes gradually from the duodenum to the terminal ileum. In the duodenum and upper jejunum there is a series of tall circular folds of mucosa, called the valvulæ conniventes. These valves are composed of the mucosa and the submucosa, and while they exist throughout most of the whole intestine, they are less abundant and less prominent toward the ileum and in the lower part of the ileum they disappear entirely. They increase the absorbent surface of the mucosa and are not materially changed by distention or contraction of the intestine.

**The Histology of the Small Intestine.**—The serous coat of the small intestine is the peritoneum similar to that of the stomach.

The muscular coat consists of an outer longitudinal and an inner circular coat, which are separated by a thin connective tissue layer. All of the muscle is unstriped. The circular layer is much thicker than the longitudinal. These coats are to some extent continuous with the corresponding muscular coats of the stomach, particularly along the lesser curvature. At the end of the pylorus there is, of course, a very sudden transition from the thick powerful circular muscle of the pylorus to the comparatively thin and weak muscle of the duodenum.

The submucosa is similar to the submucosa in the stomach, except that in the duodenum, and to some extent in the pyloric region of the stomach adjoin-

ing the duodenum, the submucosa contains peculiar branched mucous glands called the duodenal glands, or Brunner's glands. The muscularis mucosæ forms a complete layer in the small intestine except in the duodenum, where it is penetrated by the duodenal glands.

The mucous membrane of the small intestine may be divided into an inner and an outer zone. The inner zone nearest the lumen consists of long, rather slender, projections called villi. These are covered with tall columnar epithelium, in which are many large cells secreting mucus, called goblet cells. The villi, which are characteristic of the small intestine, naturally increase the surface of the interior of the intestine and consequently add to the capacity for absorption. The outer zone of the mucous membrane, which is beneath the inner zone, comprises all of the mucosa between the base of the villi and the muscularis mucosæ.

The corium of the small intestine is the stroma, in which the intestinal glands are imbedded, and forms the supporting structure of the villi. It is a fibroreticular structure and is extensively infiltrated with lymphocytes.

In many portions of the mucosa of the small intestine there are isolated nodules of lymphoid tissue, which are called solitary nodules. In the lower small intestine, particularly in the lower ileum, these solitary nodules are grouped together and form areas called agminate nodules or Peyer's patches. Some of the nodules occur throughout the small and the large intestines, but the Peyer's patches are found almost entirely in the ileum. These solitary nodules resemble other lymph nodules. While they vary in size, most of them are large enough to fill the whole thickness of the mucous membrane and push aside the adjacent intestinal glands. Very few villi project from the surface of the mucosa over these lymph nodules. A large solitary nodule may produce a marked elevation on the surface of the mucosa, and at the same time break through the muscularias mucosæ and impinge on the submucosa. The agminate nodules, or Peyer's patches, accumulate along the free border of the intestine opposite the mesentery. There are usually about thirty of these agminate nodules, each of which may contain fifteen or more solitary nodules. Sometimes these nodules are confluent, though each nodule usually contains a thin capsule. The agminate nodules form a superficial elevation on the mucosa and enter the submucous coat. In doing this they disarrange the muscularis mucosæ, which may be found between the individual nodules. Very few villi are found on the surface. The largest nodules are in the center of the patch, the smallest along the margins. They become seats of infection, particularly in typhoid fever.

In the upper part of the duodenum dense lymphoid tissue infiltrates the duodenum quite extensively, and much of this is arranged as lymph nodules with the usual germinal centers. This tissue is penetrated by the ducts from the duodenal or Brunner's glands so that these glands form a bed upon which the lymphoid tissue rests. In the duodenum the lymphoid tissue is more confluent and diffuse than in the ileum, and is also more deeply situated.

The intestinal villi have the chief function of absorption. They are slender and long, varying from one half to one millimeter in length, and

are somewhat conical in shape, the base being slightly broader than the apex. They vary in shape, however, with the different portions of the intestine, being foliate shaped in the duodenum, conical or club-shaped in the jejunum and slender and thread-like in the ileum. The villi are considerably more abundant in the duodenum and upper jejunum than in the ileum. The structure of an individual villus is formed first of all by the corium, which has been mentioned. The covering is of the lining epithelium, slender columnar cells and goblet cells. In its central portion the villus contains a rather large lymphatic, or lacteal, which arises in the inner third and passes outward through the corium to empty into the lymphatic plexus which lies just within the muscularis mucosæ. Sometimes the villus contains more than one lacteal. At the base of the villus the lacteal is surrounded by small bundles of smooth muscle fibers, which are arranged in an axial direction. This muscle is derived originally from the muscularis mucosæ and many of its fibers pass outward and are attached to the basement membrane of the intestinal epithelium along the sides and at the tip of the villus. This muscle is essentially for the rhythmic contraction of the villus in expelling the material absorbed into the lacteals.

One or more arterioles enter each villus at its base, and passing to the inner third form capillary plexuses by the extremity of the lacteal and at the apex of the villus. From this plexus minute veins proceed along the course of the lacteal, joining the venous plexus in the deeper portion of the mucosa.

The lining epithelium of the intestine, which consists of the columnar and goblet cells, rests upon a distinct basement membrane. The large peculiar shaped goblet cells are frequently found. The columnar cells show when properly stained a striated cuticular border. They have finely reticulated cytoplasm, with an oval-shaped nucleus at the base of the cell. Not infrequently the cytoplasm contains minute droplets of fat which are in the process of absorption. Sometimes leukocytes penetrate the epithelial coat and enter the intestinal canal.

The intestinal glands, or mucous crypts, or glands of Lieberkühn occur throughout the intestinal tract. They are arranged as simple tubules occupying the deeper zone of the mucous membrane. In the small intestine the neck of these glands opens between the bases of the villi. Around these glands is a diffuse lymphoid tissue of the corium. Their epithelium rests on the basement membrane and consists of three general types, the columnar cells, the goblet cells, and the granule cells. The columnar and goblet cells are similar to those which cover the villi, but the columnar cells that line the neck of the intestinal glands are somewhat peculiar. They have a very indistinct cuticular border which is entirely absent in the fundus cells. The epithelium of the glands, unlike that of the villi, takes no part in the absorption, and consequently contains no fat globules. The function of these glands is secretion of mucous fluid. Many mitotic figures are found in the epithelium at the neck of these glands, whereas such changes are infrequent at the fundus of the glands or on the villi. For this reason it has been supposed that the

cells at the neck are not fully differentiated and furnish cells which may later become either the goblet or the columnar cells of the villi, and probably also the secreting cells which line the gland. The granule cells are confined to the depth of the fundus gland. Their exact function is unknown. They seem to be true secreting cells. Other granular cells have been described both in the fundus of the intestinal glands and on the covering of the villi.

The duodenal, or Brunner's, glands are tubulo-acinar and produce a mucous albuminous secretion. They occur chiefly in the first portion of the duodenum and around the duodenal papilla. They differ from the pyloric glands by their much larger size and the fact that the secreting portion of the gland is in the submucosa and the deepest portion of the mucous membrane. This type of gland extends over into the mucosa of the proximal portion of the pyloric part of the stomach. The ducts of these duodenal glands open between the villi in rather long, crypt-like tubules that are lined with tall epithelium and resemble very closely adjacent intestinal glands. The secreting epithelium is a tall columnar cell. The gland has a wide lumen. When these cells are swollen with secretion they are clear, but after activity become shrunken and granular. A spheroidal nucleus at the base of each cell becomes flattened when the cell is filled with secretion.

The blood supply of the intestines is arranged in a similar manner to that of the stomach. The mesenteric vessels, surrounding the intestine in the subserous tissue, penetrate the muscular coat to form an intramuscular and a submucous plexus. The adjoining tissue is supplied with nourishment from these plexuses. The arteriole to the villi which has been described arises from the submucous plexus.

Lymphatics or lacteals after emptying into the lymphatic plexus of the intestinal glands pass to the lymphatic vessels in the submucosa, and from the submucous plexus numerous lymph vessels enter the muscular coat, receiving lymph from the vessels in the intramuscular septa, then entering into the larger lymphatics or lacteals of the mesentery which are connected with the mesenteric lymph nodes. In this manner the chyle is permitted to come into relation with the sinuses around the bases of the lymph nodules which are scattered through the intestine.

The nerve supply of the intestine is similar to that of the stomach. The non-medullated fibers constitute an intramuscular myenteric ganglionic plexus, or Auerbach's plexus, which supplies the muscular coat and the submucous plexus, or Meissner's plexus, which supplies the structures of the mucosa. Some of the smallest branches enter the villi and form a fine nerve plexus about the vessels and lacteals of the villi and under the epithelium.

**Surgical Anatomy of the Small Intestine.**—The surgical anatomy of the small intestine has been studied by Dr. George H. Monks, of Boston, who has made a valuable contribution to this subject. According to Monks, the small intestine is located in three zones of the abdomen, which are determined by drawing two lines through the abdomen, one through the upper end of the mesentery and the other through the lower end, these being perpendicular to the axis at the root of the mesentery. The upper third of the small intestine

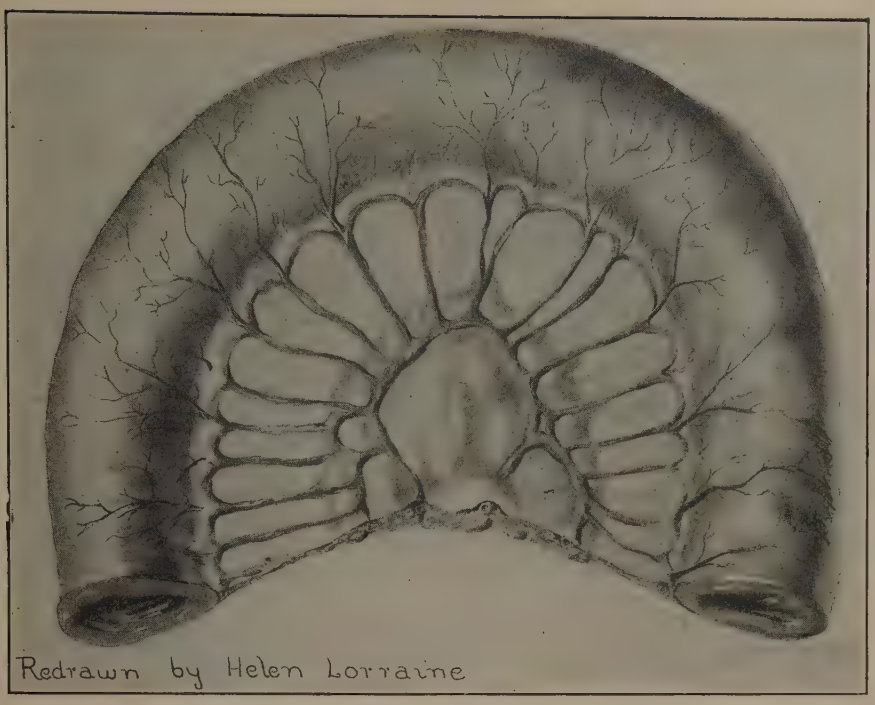


FIG. 7.—A LOOP OF INTESTINE, THE MIDDLE OF WHICH IS EXACTLY THREE FEET FROM THE END OF THE DUODENUM.

The gut is of large size. The mesenteric loops are primary and the vasa recta are long and regular in distribution. The translucent spaces (lunettes) are extensive. Below, the mesentery is streaked with fat. The veins, which had a distribution similar to the arteries, are for simplicity omitted from this and from the subsequent drawings. (After Monks.)

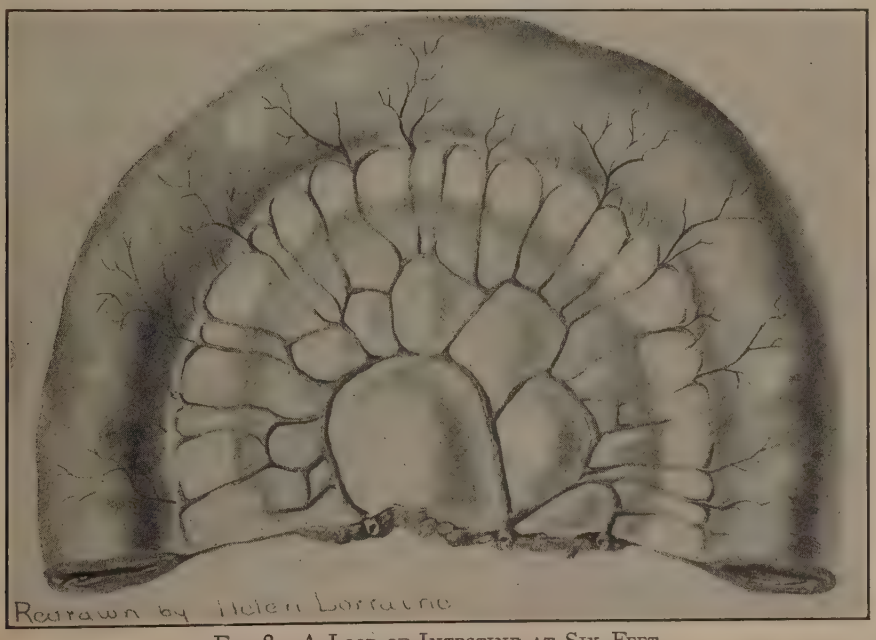


FIG. 8.—A LOOP OF INTESTINE AT SIX FEET.

As compared with the preceding figure the gut is somewhat smaller and the vascularity of the intestine and of the mesentery is less. Secondary loops are a prominent feature. The vasa recta are smaller. The lunettes are also present, but are not so large as in the preceding figure. (After Monks.)

lies chiefly in the left hypochondriac region. The middle third lies chiefly in the middle zone of the abdomen, or more accurately between these two lines, and the lower third lies chiefly in the pelvis and the right iliac fossa.

The diameter of the small intestine has been already mentioned. It is largest above, and gradually diminishes until it reaches the lower third of the small intestine, when it appears to remain the same size from that point throughout. The upper small intestine is also thicker than the lower, and the valvulæ conniventes can be readily felt. The intestine becomes thinner until its lower third, when the thickness remains the same until about 3 feet (91.5 cm.) from the ileocecal valve, when the intestinal wall seems to thicken, probably due to increase of the muscular coat. In the upper part of the small intestine the color is bright pink or red. This gradually fades out to a grayish color in the lower small intestinal wall. The vascularity decreases as the bowel is followed from above downward.

One of the most striking features in the changes of the small intestine is the difference in vascularity in the upper jejunum and in the lower ileum. The branches of the mesenteric vessels that supply the upper small intestine are larger than those that supply the lower. The vessels seem gradually to grow smaller from above downward until they reach the lower third of the small bowel, when they remain about the same size to the termination of the ileum. The arrangement of these vessels is quite different, and this is one of the most striking features that has been pointed out by Monks. The main branches of the superior mesenteric artery follow loops which Monks has called primary loops. In some parts of the mesentery there are three series of loops, the secondary loops being formed from branches of the primary loops, and tertiary loops from the secondary loops. From the loops nearest the bowel small straight vessels, vasa recta, run directly to the bowel to which these branches are distributed. The mesenteric veins are arranged in a similar manner. In the mesentery of the upper jejunum, there are chiefly primary loops, though occasionally a secondary loop which is much smaller than the primary loop occurs. Primary loops are always large and regular. Farther down the secondary loops become more numerous and larger, and approach more nearly to the margin of the intestine than do the primary loops in the upper part of the small intestine. According to Monks, these secondary loops become prominent at about the fourth foot (122nd cm.). When the secondary loops become prominent the primary loops are seen to be smaller. In the mesentery of the lower ileum the loops lose their characteristic appearance and are represented chiefly by a complicated network. In the mesentery of the upper jejunum the vasa recta are from 3 to 5 cm. long when the loop of intestine is gently stretched. These vasa recta are large and regular, run in a straight direction, and rarely give off branches in the mesentery. In the mesentery of the lower third of the small bowel they are short—usually less than one centimeter in length—smaller, less inclined to be straight, more irregular, and often give off branches in the mesentery.

There is also a marked difference in the mesentery of the upper small

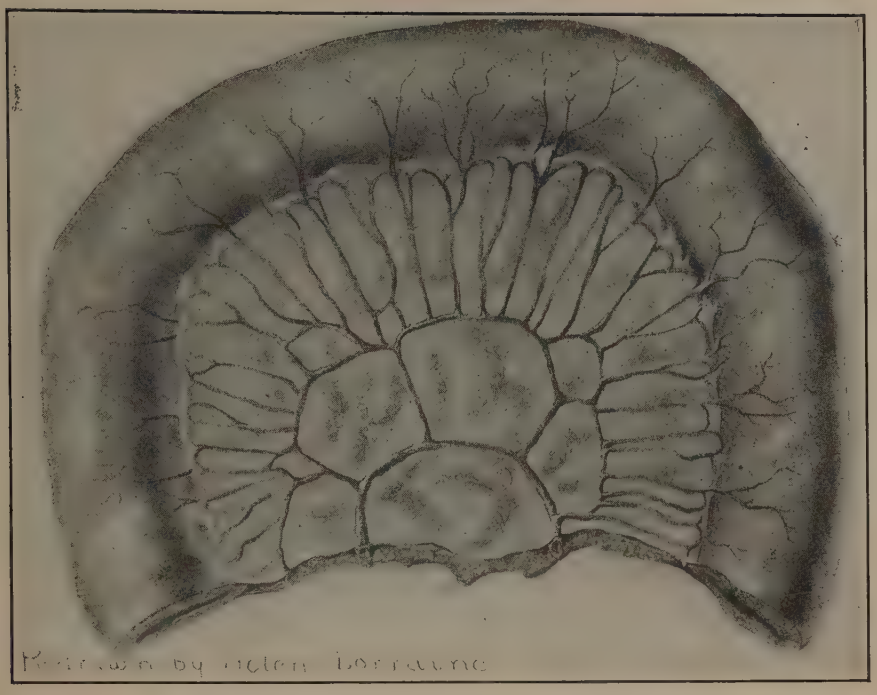

FIG. 9.—A LOOP OF INTESTINE AT NINE FEET.

The secondary loops are large, and the vasa recta are somewhat irregular and show branches. No lunettes are present, and the mesentery is streaked with fat, and is, therefore, somewhat opaque. (After Monks.)

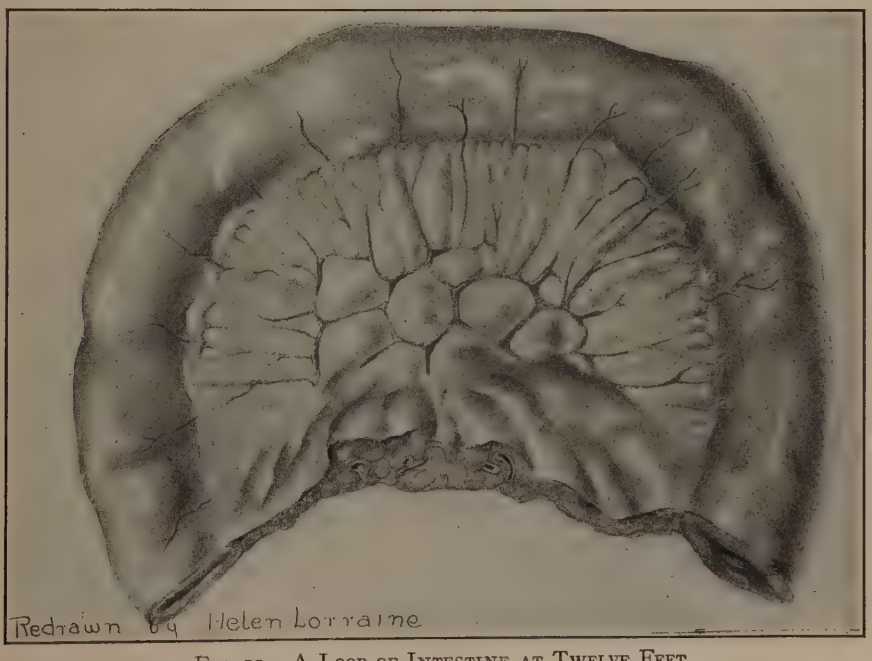


FIG. 10.—A LOOP OF INTESTINE AT TWELVE FEET.

The vessels are smaller. The primary loops are lost in the fat, but secondary and even tertiary loops are visible. The vasa recta are shorter, more irregular, and branching. (After Monks.)

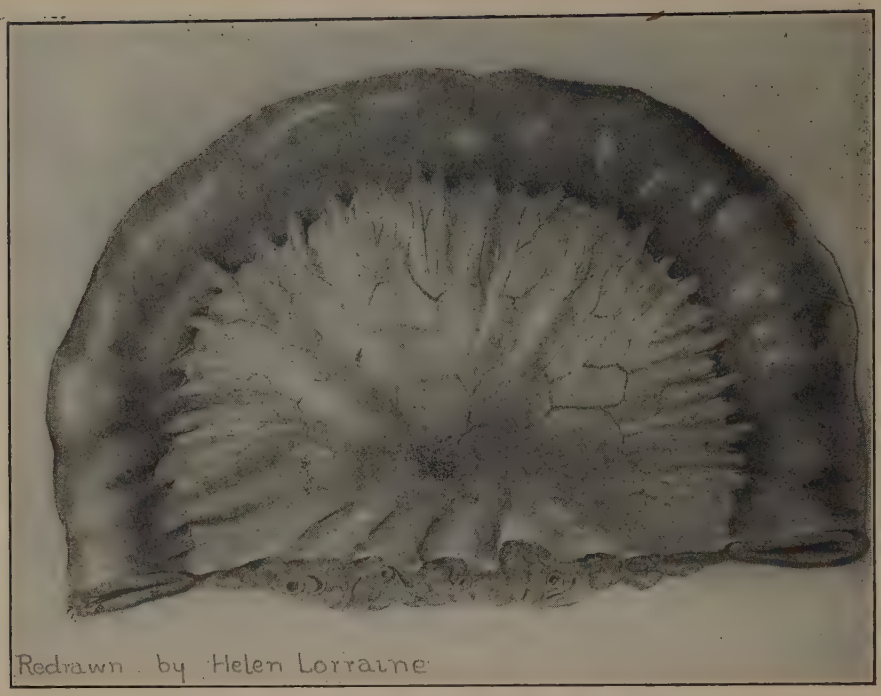


FIG. 11.—A LOOP OF INTESTINE AT SEVENTEEN FEET.

The mesentery is opaque and small tabs of fat begin to appear along the mesenteric border of the gut. The vessels are represented by a somewhat complicated network, and are seen with difficulty in the thick fat of the mesentery. (After Monks.)

FIG. 12.—A LOOP OF INTESTINE AT TWENTY FEET.

The gut appears to be thick and large. The mesentery is quite fat and opaque, and large and numerous fat tabs are present. The vessels, which are complicated, are seen with difficulty, and are represented by mere grooves in the fat. (After Monks.)

intestine and of the lower ileum. Naturally the difference also varies in different individuals. In thin persons the mesentery is more translucent than in the fat. The thinnest section of the mesentery is that portion attached to the upper jejunum and the mesentery becomes thicker farther down the small gut. This increase in thickness seems to be due chiefly to a deposit of fat, but also to a certain amount of fibers and some muscular tissue that aids in the support of the lower intestine. In very fat persons the mesentery is fat throughout, but this is particularly prominent in the lower ileum, where the vessels in such persons cannot be seen and are recognized only by groove-like depressions in the mesentery over the large vessels. In the upper part of the small intestine there are in the portion of the mesentery close to the gut small transparent spaces between the vasa recta. These are called by Monks "lunettes," and are practically always present in this region even when the mesentery is thick. Lower down they become smaller, streaked with fat, and finally disappear about 8 feet (2.44 m.) from the beginning of the jejunum. Sometimes in the emaciated they may persist to the end of the gut (Figs. 7-12).

In everyone except the thinnest individuals small masses of fat project from the mesentery toward the intestine and sometimes extend onto the intestine. In a very fat person these tabs occur throughout the intestines, but they are usually confined to the lower third of the small bowel.

In a median line incision the length to which the mesentery of a loop of bowel can be stretched may also be of service in localization of the loop. Thus Monks has found that a loop of bowel from the first foot of the jejunum can on an average be drawn to a point about 3 inches (7.7 cm.) above the pubis, while in the lower ileum the loop can be drawn to a point as far down as 1 to 3 inches (2.5 to 7.7 cm.) below the pubis. When a loop of intestine is pulled out from the abdominal wound, gentle traction will demonstrate the direction of the mesenteric attachment, and will in a manner give some idea as to the part of the bowel by estimating the portion of the mesenteric root from which the mesentery to this particular loop arises. When the loop is held by an assistant, the finger is guided down to the left of the loop. If it is seen that the finger enters in the free surface on the left side it indicates that the mesentery is not twisted and the direction of the bowel is easily determined.

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## CHAPTER III

## PHYSIOLOGY OF THE STOMACH AND SMALL INTESTINE

The physiology of the stomach may be divided into the motor functions, or mechanism of digestion, and the secretory functions.

### THE MECHANISM OF GASTRIC DIGESTION

There is a distinct sphincter at the cardiac portion of the stomach which guards the entrance of the esophagus into the stomach. This is usually contracted, or in constant tonus, which of course is varied from time to time by temporary relaxation and rhythmic alterations of contraction and relaxation. The tonus of the cardiac sphincter is never very great. It will stand much more pressure from within the stomach than from the esophagus. Repeated swallowings decrease the tonus and after a number of consecutive swallowings the sphincter sometimes becomes completely relaxed. After this relaxation, however, the tonus of the sphincter is higher that it was before. The contraction of the cardiac sphincter is controlled by the vagus nerve. Stimulation of the vagus nerve will cause relaxation, followed by a very strong contraction. Mechanical or chemical stimulation of the lower portion of the esophagus increases the contraction of the cardiac sphincter.

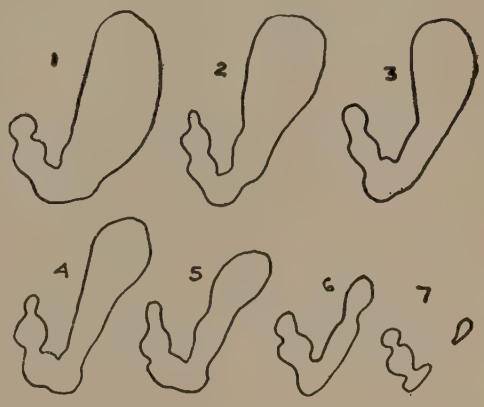


FIG. 13.—OUTLINE OF THE ROENTGEN-RAY SHADOWS CAST BY THE STOMACH OF A CAT AT HOURLY INTERVALS AFTER INGESTION OF FOOD CONTAINING BISMUTH. (From Cannon.)

The appearance is quite similar to the stomach of man. There is change from a pyriform shape to a tubular outline, with the lesser curvature remaining almost stationary and the greater curvature approaching the lesser curvature.

The eructation of gas requires much more force to overcome the sphincter from the side of the stomach than would swallowing from the esophageal side. After a meal very frequently the tone of the cardiac sphincter varies, and occasionally there is regurgitation of some of the gastric contents into the esophagus as high as the heart, and sometimes into the pharynx and mouth. This usually starts a peristaltic wave, however, which quickly forces the gastric contents back into the stomach. The lower portion of the esophagus is supplied with smooth muscle,

and the upper with voluntary muscle, so that the motion in the lower part of the esophagus is much slower than in the upper part. Regurgitation of food into the esophagus only occurs when the pressure in the stomach is fairly high.

FIG. 14.—THIS AND THE SUCCEEDING FIVE ILLUSTRATIONS SHOW THE EMPTYING AT HOURLY INTERVALS OF AN APPARENTLY NORMAL STOMACH.

The stomach has been filled by swallowing barium and buttermilk, and the roentgenogram has been taken immediately. The stomach is of the fishhook type. (This and the succeeding five roentgenograms were made by Dr. Fred M. Hodges.)

A short time after the stomach is filled with food, peristaltic waves begin about the middle of the body of the stomach and pass toward the pylorus. The portion of the stomach to the left of the origin of the waves, the cardiac half of the body of the stomach and all of the fundus, usually called the

cardiac pouch, does not definitely participate in the peristaltic waves, but is in a state of tonic contraction and acts like an elastic hopper, pushing the food toward the pyloric end. As the stomach empties the peristaltic waves begin farther toward the left of the stomach than when the stomach is full. As

FIG. 15.—ROENTGENOGRAM OF THE STOMACH SHOWN IN FIG. 14 AN HOUR LATER.

the stomach empties, the cardiac pouch gradually reduces in size, and from being pyriform when the stomach is full, usually becomes tubular (Fig. 13). When the waves of peristalsis begin they do not progress as a band of constriction, but show alternately periods of increased and diminished tone, of contraction and relaxation (Figs. 14-19).

Between the phase of complete relaxation and the reappearance of a similar

phase, is what is known as a gastric cycle. Sometimes a peristaltic wave requires but one cycle to complete its journey from its origin to the pylorus and would show one period of complete relaxation and one period of greatest contraction. There are also types of peristaltic waves in which there are two,

FIG. 16.—ROENTGENOGRAM OF THE STOMACH SHOWN IN THE TWO PRECEDING FIGURES TWO HOURS AFTER INGESTION OF THE BARIUM.

three, or four or more gastric cycles during the passage of the wave, and consequently in the latter types several different waves of peristalsis can be detected at the same time. The most common type is the four-cycle type. A gastric cycle lasts from two to three seconds. The time for a four-cycle peristaltic wave from its origin to the pyloric sphincter is from eight to

twelve seconds, though it does not often exceed ten seconds. Cole divides gastric cycles into a systole and a diastole. The systole takes seven-tenths of the period of the cycle, while the diastole requires three-tenths. The chief control of peristalsis is probably within the stomach itself, though the extrinsic nerves, the vagi and the splanchnics, have much to do with regu-

FIG. 17.—ROENTGENOGRAM OF APPARENTLY NORMAL STOMACH OF FISHHOOK TYPE, TAKEN IMMEDIATELY AFTER THE INGESTION OF THE BARIUM AND BUTTERMILK MIXTURE.

lating peristalsis. Section of both vagi below the level of the heart causes relaxation of the stomach and a lessened tone, though the tone is not entirely abolished. The tone varies and may become very pronounced. After section of the vagi below the heart hunger pains are diminished, both in regularity and in the rate at which they appear. Section of the splanchnic nerves increases the tone of the stomach and seems to augment hunger contractions. When both the splanchnic and vagus nerves are divided, the tone of the

stomach is decreased, though in prolonged starvation contractions will develop. In other words, though section of the extrinsic nerves has a rather marked effect upon the movement of the stomach, gradually the tone of the stomach seems to recover and digestion proceeds.

FIG. 18.—ROENTGENOGRAM OF THE STOMACH SHOWN IN THE PRECEDING FIGURE, TAKEN AN HOUR LATER.

The whole question of the function of the extrinsic nerve supply of the stomach and intestine has undergone considerable revision of opinion in recent years. Many physiologists, such as Thomas and Wheelon, Brunemeier and Carlson, and others, have shown that the simple theory that the vagi carried all

the motor extrinsic nerve impulses of the stomach and intestines and that the splanchnic conducted all of the inhibitory impulses does not hold. From the work by Carlson and Litt, in which a new method is used for detecting the motor function of the pyloric end of the stomach, proof seems quite

FIG. 19.—ROENTGENOGRAM OF STOMACH SHOWN IN FIG. 17, TAKEN TWO HOURS AFTER THE INGESTION OF BARIUM AND BUTTERMILK MIXTURE.

About the middle of the roentgenogram is shown the tubular approximation of the greater and lesser curvatures described by Cannon as occurring in a cat. The rugæ of the stomach are distinct in the picture. On the left is seen the duodenal cap. The stipple-like area below the stomach is the barium in the small intestine.

definite that both motor and inhibitory impulses for the pylorus enter the stomach by both the vagi and the splanchnic nerves. They find that types of pylorospasm may be decreased or abolished "by (*a*) section of the vagus nerves, (*b*) by section of the splanchnic nerves, (*c*) by stimulation of the peripheral end of these nerves. There are states of atonicity of the pylorus

that may be relieved by section of the vagus nerves. These facts indicate that states of spasm or atonicity of the pylorus may be caused by excess activity of either the vagus or the splanchnic efferents, motor and inhibitory." They also find that any irritation to the mucosa of the duodenum causes reflexly a closure of the pyloric sphincter. This closure was produced by weak acids, weak alkalies, or even a small amount of water. Acids or alkalies cause a more marked pylorospasm than water, and when the acid was strong the pylorospasm was increased both in vigor and in duration. When the duodenal mucosa is abnormally irritable, as from an ulcer, the reflex closure of the pylorus may be accomplished merely by the acid or neutral contents of the stomach or by alkaline bile in the gastric juice, which may account for the marked and continuous pylorospasm sometimes found in the presence of an ulcer of the duodenum or of marked irritation of the duodenum.

Mechanical or electrical stimulation of any afferent nerve of the abdominal viscera may produce a spasm of the pylorus and these reflexes persist even after section of both vagi in the neck. This goes to show that the reflex is not dependent upon the vagi.

Cannon states that experiments in his laboratory show that stimulation of the vagi by an electric current may produce either contraction or relaxation of the pylorus depending upon the rapidity of the current. The same strength of current through the same electrodes would produce increased tone of the stomach if applied slowly or inhibition of tone and activity if applied rapidly.

While mechanical or chemical stimulation of the duodenal mucosa produces a reflex closure of the pylorus, the mechanism which tends to open the pylorus seems to be dependent to some extent upon the general action of the peristalsis of the stomach. Cannon's theory of the chemical control of the pyloric sphincter, which is an elaboration of the work of Pavlov, was not intended to mean that this was the sole method of opening and closing the pyloric sphincter, but merely one of the methods.

When food first reaches the stomach it lies along the greater curvature and forms a layer on which rests the subsequent portion of the food swallowed. The first layer takes up to a large extent the gastric juice and as strong peristalsis is not at once initiated, the last food that is swallowed in a large meal remains comparatively isolated at the cardiac portion of the stomach and separated from the greater curvature and most of the mucosa by the layers of food previously swallowed. In these conditions the digestive ferments of the mouth continue to act, and a considerable amylolysis occurs. The ptyalin from the mouth acts in an alkaline or, better still, in a neutral medium. As soon as the food contents are thoroughly mixed with the gastric juice by peristalsis, and there is a marked acid reaction, the action of the ptyalin of course ceases. The food is carried forward to the pylorus by the peristaltic waves, which act somewhat as the waves of water do in floating a cork to shore. Each wave of peristalsis carries some of the gastric contents a little farther toward the pyloric end, but it is not forced immediately to the end as it would be if the peristaltic waves caused a complete contraction,

or, in other words, in an action like milking. It has been shown by staining the last food swallowed that the pyloric end of the stomach will have no trace of coloring matter for twenty minutes after food has been swallowed into the cardiac end. Then traces will appear, and afterwards a large quantity with complete mixture.

The food in the pyloric end is a semifluid, and consistent in character, whereas in the cardiac portion it is lumpy and irregular. Each of the peristaltic waves tends to bring more food in contact with the mucosa.

The emptying of the stomach is somewhat complicated. It was formerly thought by Pavlov, whose views were elaborated by Cannon, that the action of the pyloric sphincter depended upon the acid and alkaline contents of the stomach and duodenum respectively. It was believed that when the contents of the stomach were strongly acid the sphincter opened, and that when the contents of the duodenum became acid the sphincter closed. Further study, however, showed that this is not the chief cause of the action of the pyloric sphincter, if, indeed, it has any marked effect on this sphincter. That such a chemical change could not be the sole cause of pyloric action can be obviously seen in cases of achlorhydria, in which there is no acid in the gastric juice. Then the action of water and of egg albumin, which are quickly discharged from the stomach and are often of neutral reaction when they reach the duodenum, cannot be explained by such a mechanism. There is doubtless a coördinated movement between the stomach, the pyloric sphincter, and the first part of the duodenum.

The work of Luckhardt, Phillips, and Carlson, which combined fluoroscopic observation with graphic records obtained by a balloon placed in the stomach, showed that the passage of chyme into the duodenum seems to coincide with the gastric peristaltic waves. Thomas and Wheelon have also shown by a balloon inserted in the antrum and pyloric canal that there is marked correlation between the movements of the antral portion of the pyloric end of the stomach and the sphincter. According to them, when a gastric peristaltic wave reaches the antrum, the sphincter becomes somewhat relaxed. If the wave is sufficient to involve simultaneously the whole antrum of the stomach and the pyloric sphincter before the wave disappears from the antrum, both the sphincter and antrum appear to be contracted. Soon after this, however, the antrum relaxes and the sphincter is still contracted. Fluoroscopic examination seems to show that some chyme escapes through the sphincter with each passage of the peristaltic wave over the antrum.

Thomas and Wheelon in subsequent observations showed that there is an intimate connection between the activities of the duodenum below the reservoir cap and the movement of the antrum and the pyloric sphincter. When simultaneous tracings were made of the antrum, the pyloric sphincter, and of the duodenum below the cap, it was seen that the duodenum enters its positive phase two and a half seconds after the beginning of the contraction of the pyloric sphincter, and at this moment the antrum relaxes and remains relaxed while the sphincter and the duodenum are contracted. The pyloric sphincter begins its phase of relaxation shortly before the maximal contraction of the

duodenum and the maximal relaxation of the duodenum occurs just after the beginning of the contraction of the pyloric sphincter.

The peristaltic waves of the duodenum below the cap aid in withdrawing material from the cap which receives the chyme while the antrum of the stomach is contracted. This chyme cannot return to the antrum with the antrum relaxed, because the pyloric sphincter remains closed. Consequently the motility of the stomach seems to influence the peristalsis of the duodenum and so indirectly aids in the emptying of food in the cap.

The motility of the duodenum also influences the pyloric sphincter, because stimulation below the cap produces not only a contraction at the stimulated point with some relaxation below, but causes a contraction of the pyloric sphincter, which is followed by prolonged relaxation. In this way the action of the pyloric sphincter unassociated with the contractions of the pyloric end of the stomach can be induced.

The first meal after starvation the stomach discharges much more quickly than a meal taken a few hours after the first meal.

## THE MECHANISM OF DIGESTION IN THE SMALL INTESTINE

The intestinal tract is much more extensive in the herbivora than in the carnivora, as there is relatively more cellulose in a purely vegetable diet and it takes a longer intestinal tract to extract the nourishment. Practically the whole of the digestion of the cellulose is in the intestine. For some time after feeding there is apparently no unusual movement in the column of food, then the column is broken up into small segments of about the same size and each of these is again quickly divided, so that a half of each segment unites to a half of an adjoining segment to form a new segment.

This movement was first fully described by Cannon and is called by him rhythmic segmentation. It continues for half an hour or more, and during this time the food does not change its position in the abdomen and the bulk of the food makes practically no forward or backward movement. This segmentation proceeds with great rapidity, sometimes the rate of division in a cat is as high as 28 or 30 times per minute, while in man it occurs at the rate of about 10 times per minute. These movements are caused by narrow rings of contraction and under these movements the loops of intestine sway from side to side. There are also very slight waves of contraction which pass quickly along the intestine, and follow each other at the rate of about 12 a minute. Both the internal circular and the external longitudinal muscular coats of the intestine function in producing these movements, which are accentuated when the mechanical stimulus of masses of food is offered and seem to spring from where the tension in the intestine is greatest.

These movements serve to mix the food with the natural juices of the intestine and promote absorption by bringing the food in thorough and frequent contact with the mucosa. The movements also have an important

function in massaging the blood and lymph vessels in the intestinal wall and so facilitating the emptying of these vessels. The flow of lymph in the lacteals is probably entirely dependent upon these movements.

The other movement of the intestine is the peristaltic wave. The peristaltic wave may be a contraction slowly advancing at the rate of one or two centimeters a minute and preceded by a relaxation of the muscular coat in that portion of the intestinal wall immediately in front of the contracting area. These waves are short, and only travel from four to five centimeters. Another type of peristaltic wave is known as the peristaltic rush, and is a swift wave of contraction that travels very much longer distances of the intestine. When the extrinsic nerves of the intestines are cut it is found that the splanchnic nerves as a rule carry inhibitory impulses except to the ileocolic sphincter, for after section of these nerves the movements of the intestinal muscles seem to be more marked while stimulation of the peripheral end of the nerves appears to inhibit peristalsis that may be already in progress. The vagi are supposed to carry motor impulses.

The circular coat of the terminal ileum for two or three centimeters is thick and appears to act as a sphincter, somewhat like the pyloric sphincter in the stomach. This sphincter opens when food reaches it from the ileum, but closes against pressure from the cecum. It is under different control from the rest of the ileum, because it is not affected similarly by the splanchnics or vagi. Irritation of the splanchnics causes a contraction of this sphincter, whereas stimulation of the vagi does not affect it.

The so-called "law of the intestine" of Bayliss and Starling, seems to indicate that when the gut is pinched or irritated a marked relaxation occurs in the caudad region of the intestine, while there is contraction above and at the area of irritation. Considerable doubt has been cast upon this physiologic law by the work of Alvarez, whose findings of the intestinal gradient do not agree with this law of Bayliss and Starling.

Cannon has called attention to some of the objections to this law. It is difficult to demonstrate experimentally, and is exceedingly irregular. The inhibition below the point of stimulation is notoriously difficult to demonstrate in many instances. Frequently the bowel in front of a wave of contraction also contracts, and if this were not true it would be difficult to see what would stop every on-rushing wave of peristalsis until the food was completely emptied from the intestinal tract. Clinical experience, too, seems to show the law of the intestine does not hold, because it is a common observation when patients are operated upon for mechanical obstruction to find the bowel dilated just above the point of obstruction and firmly contracted below it. The dilatation above is, of course, due to the accumulation of gas and the increase of the fluid contents and intestinal secretion, as well as to the later weakening of the peristalsis from exhaustion of the muscle of the bowel. But the marked contraction of the bowel below an organic obstruction, which serves as a local irritant, is not in keeping with the law of the intestine, which holds that there is dilatation below the point of irritation.

Keith's theory as to the nodes in various portions of the gastro-intestinal

tract serving as pacemakers has doubtless arisen from hasty conclusions. Keith's investigations were anatomical, not physiological. He found small collections of nodal tissue about the cardia of the stomach and the ileocecal sphincter. He assumed that there might be other collections of this tissue in the jejunum, duodenum, and other small intestine. He suggested that "food is propelled through a series of zones or segments, each furnished with its own pacemaker and its own rhythmical contractions." The conclusions were reached that the intestinal contractions occurred in the same way as the contraction of the heart, but the contraction of the heart is, of course, exceedingly rapid as compared with peristalsis of the stomach and intestine. Each segment of the intestine apparently contracts at its own rate, so far as rhythmic contraction is concerned, though the peristaltic rushes may go some distance over adjoining segments. Alvarez and Miss Starkweather, after studying regions described by Keith, counted the rate of rhythmic contractions in these regions and in the adjoining portions of the stomach and intestines, both before and after severing them, and found no evidence of any zones or of any domination in rhythmic contraction of one segment over another.

Alvarez has made very interesting observations in a study of the peristaltic rush. This work was done by new methods which he devised, and he finds that the peristaltic rushes in rabbits usually begin in the duodenum and travel faster the farther they go down the bowel. The peristalsis at first in the upper small intestine is at the rate of from 2 to 4 cm. (0.8 to 1.2 inches) per second, but when the rush reaches the lower ileum it may be traveling at the rate of from 7 to 25 cm. (2.75 to 9.8 inches) a second. When the peristaltic rush travels rapidly over the ileum, it usually has begun in the duodenum. When the rate of the peristaltic rush over the ileum is the same as the contractions of the duodenum it is found that this type of rush begins in the ileum. The fast rushes generally leave the pylorus just before a gastric peristaltic wave arrives, and often before the stomach has had time to empty into the duodenum. By observation under the fluoroscope the findings in the rabbit seem to be duplicated in man, and the rate of travel of the rushes appears to be about the same.

In the article on the law of the intestine, or the myenteric reflex, by Alvarez many very interesting experiments are noted, done under the new technic devised by him, the work being mostly on rabbits. The similarity of the peristalsis of rabbits to that of man has been strikingly shown as compared in observations under the fluoroscope. It is well known that the law of the intestine, or the myenteric reflex, means, as stated by Bayliss and Starling, that "excitation at any point of the gut excites contraction above, inhibition below." Alvarez and Miss Starkweather studied 239 records by the new method and found that in about one-third of these cases there was a descending inhibition in front of the advance of food. A contraction wave ahead of the peristaltic rush wave was found in 38 per cent and in about 27 per cent there was no inhibition. In other words, in only about one-third of these cases was observed the phenomenon of the law of the intestine or the myenteric reflex of contraction above the point of irritation and a dilatation below. He found, too, that

peristalsis would jump a considerable gap and when two ends of the intestines were divided and tied on a glass tube so that the ends were about 1.5 cm. (.6 inch) apart, the downward peristaltic rush would jump the gap. That is, it would stop about 3 to 4 cm. (1.2 to 1.6 inches) above the gap and a new peristaltic rush would begin 2 to 3 cm. (.8 to 1.2 inches) below the gap.

Alvarez believes that the waves travel somewhat as the impulse of the heart, largely from the action current. The direction is given to the gradient by rhythmicity and metabolism. When the ripple of peristalsis is deeper and becomes a peristaltic rush, food may or may not be carried with this rush. These rushes have been observed to pass over the intestinal content, leaving it practically untouched. When, however, it deepens and pushes the intestinal content with it there is more likely to be an inhibition in front of it than when the food is not so carried. Cannon's idea that the content of the intestinal tract has much to do with initiating the peristaltic waves is generally accepted. Just how this acts is difficult to explain. Undoubtedly there is something besides the mechanical bulk. Some material seems to have the property of inciting peristalsis.

The bowel can move fluids much more easily than solids, and fluids can be handled at least without the help of the myenteric reflex, though this reflex may be called upon to help move some of the solid material through the intestine. Resistance usually is found springing up ahead of the peristaltic rush, especially in the terminal ileum, and serves the purpose of preventing a rapid evacuation of the bowel.

## THE GRADIENT THEORY OF PERISTALSIS

Very much light has been thrown upon the mechanics of the digestive tract by the work of Alvarez. This seems so important not only from the viewpoint of physiology but as an explanation of many pathologic conditions that it should be considered at some length. The work of Alvarez, which is embodied in his book, *The Mechanics of the Digestive Tract* (Paul B. Hoeber, New York, 1922), maintains as a prime principle that many of the contractions of the gastro-intestinal tract are myogenic in origin and are to a large extent independent of nervous control. This tendency to rhythmic contraction is found, according to Alvarez, in so many different conditions in nature that it must be assumed to be a normal process and inherent in the type of smooth muscle found in the gastro-intestinal tract. Thus, he finds that strips of muscle taken from the intestine or stomach and without even the attachment of fibers from Auerbach's plexus, will contract rhythmically. Furthermore, these contractions seem to be stronger after the strips have been kept for a few days under proper conditions than they were at first. As some sympathetic nerve ganglia do not function even a few minutes after circulation has ceased, it seems improbable that this rhythmic contraction is due to nerves, even if they had not been carefully eliminated, because the contraction is better after one or two days than it was at first. Though the muscle con-

tracts rhythmically by itself, it is under normal conditions in close relationship to its nerves. Alvarez believes that the function of Auerbach's plexus is chiefly to conduct unusual stimuli and to coördinate movements.

According to Alvarez, impulses pass through the myenteric plexus at the rate of about 20 cm. (7.8 inches) a second, while the rush waves of peristalsis in the bowel which travel from muscle fiber to muscle fiber progress at the rate of about 4 cm. (1.6 inches) a second. In a rabbit impulses through the mesenteric nerves appear to travel at about 200 cm. (6.5 feet) a second. Auerbach's plexus seems to cause the muscle of the intestine and of the stomach to respond to stimuli from the mucous membrane. These stimuli collected by Meissner's plexus in the submucosa are transmitted by connecting nerve fibers to Auerbach's plexus and, according to Cannon, seem to be modified by the chemical nature of the intestinal contents. Auerbach's plexus doubtless also serves largely as an inhibitory influence on the muscles of the intestine, which might otherwise contract into a hard knot, when rhythmic contractions would be no longer possible. Cannon, for instance, has seen very marked contraction of the stomach into a hard tube when the extrinsic nerves are cut. Alvarez suggests that the so-called congenital pyloric stenosis in infants may be due to the absence of inhibitory influence which prevents the muscles from contracting too firmly.

Alvarez emphasizes that the chief function of Auerbach's plexus is to expedite conduction. He finds that the smooth muscle found in the gastro-intestinal tract differs in various portions of the tract and not only has somewhat dissimilar gross physical structure, but different metabolism. The muscle at the pyloric end of the stomach, for instance, is much firmer and more gristly than the muscle in the cardiac end, and the muscle in the duodenum differs in its behavior from the muscle in the large intestine. Stimulation of the different types of muscle by the electric current does not give the same results.

The smooth muscles in hollow organs respond markedly to tension, and, according to Cannon, the motor activities of the intestinal tract are largely initiated and regulated by the internal pressure due to food or gas. He has also shown that waves of contraction in the stomach tend to appear where the internal pressure balances the local tone of the muscle. Smooth muscle responds markedly to the influence of direct irritation. This is well shown in the contraction of the muscle of the stomach opposite an ulcer on the lesser curvature, and in the deformity of the duodenal cap with ulcers in this region.

Food taken in the mouth rapidly goes into the lower third of the esophagus because the upper portion of the esophagus is striated muscle. The lower portion, however, is smooth muscle and the progress here is much slower. Occasionally strong contractions of the cardia seem to throw the food back toward the mouth. The peristalsis in the stomach begins in the body or the cardiac portion of the stomach and travels first as shallow ripples, according to Alvarez. With the proper conditions of pressure when the different types of muscle along the pyloric antrum are met these ripples break into deep waves which go as far as the pylorus, but do not, as a rule, cross the pylorus. The

closure of the pyloric sphincter often precedes the apparent wave of peristalsis, though some food appears to be ejected into the duodenum with each strong peristaltic wave of the stomach that reaches the sphincter.

A few of the circular fibers of the pyloric ring go over the duodenal cap in a festoon arrangement. Some of these become practically longitudinal. The connective tissue partitions at the sphincter probably tend to stop the peristalsis to some extent, though doubtless the tugging of the muscle may transmit some impulse. Alvarez thinks that definite electric waves which he calls "action currents" precede the actual contraction of a peristaltic wave, and that the sphincter of the pylorus is sensitive to an electric current so delicate that it would not be sufficient to cause contraction of the other less sensitive muscles. Consequently, its threshold being lowered, the pyloric sphincter contracts ahead of the arrival of the peristaltic wave over the antrum of the pylorus.

Though the duodenal cap is filled during the early stages of digestion, toward the close of digestion there is usually some regurgitation of the duodenal contents into the stomach, but after food has passed the cap it quickly travels through the rest of the duodenum and jejunum.

The motions of segmentation and rhythmic contraction have already been described. The rush waves, which are the main factors in producing movement of the intestines, are often initiated as ripples in the duodenum, and these sometimes follow after a gastric wave has reached the pylorus. Occasionally they seem to follow swallowing movements, which, according to Alvarez, suggests that the origin of these peristaltic rushes may sometimes be even higher than the stomach. The rush waves seem to be stopped by the contractions ahead of them, so the slowing of the intestinal contents just above the sphincter of the ileocecal valve is at least partly due to reverse peristalsis.

The sphincter of the ileocecal valve has two definite functions, one being to hold back the food coming from above, and the other to block the regurgitation of the contents of the colon into the ileum.

Alvarez has observed the gastrocolic reflex, which was first noticed by Hurst. According to this reflex, after the contents of the ileum appear to stagnate for a while, if food is taken into the stomach the ileocecal sphincter seems to relax and the bowel contents quickly empty into the colon. The action of the ileocolic sphincter seems to resemble in many respects the action of the pyloric sphincter.

When the bowel contents are evacuated into the colon reverse peristalsis beginning in the right portion of the transverse colon seems to force the liquid contents of the bowel back into the cecum, and normally the ileocecal valve closes when this is done, so that the cecum is distended with its contents. After a while peristalsis in the normal direction begins, but the churning back and forth of the reverse peristaltic waves and the regular peristaltic waves gives the maximum opportunity, both by pressure and the movement of the intestinal contents, for the absorption of the fluid elements.

Alvarez calls attention to the fact that if the smooth muscle of a tube, like the intestine or ureter, is stimulated, there is a ring of contraction, and from

this waves of contraction, or peristalsis, proceed in both directions. If there is marked tendency for them to travel in a definite direction, they will go farther in that way than they will in the unnatural direction. He finds that the rhythmic contraction of the intestine is different in different segments of the bowel. Thus, strips from the duodenum contract usually at a rate of about twenty per minute, whereas strips from the lower portion of the ileum have a rhythmic contraction of about ten per minute. These rhythmic contractions appear to be myogenic in origin, as Alvarez has pointed out, and are to a large extent independent of the nervous impulses from Auerbach's plexus and the mesenteric nerves which serve for long reflexes as for communication between the pylorus and the lower ileum, and to regulate the peristaltic rushes or waves which tend to empty the bowel.

If there is a ring of scar tissue, as after an anastomosis of the bowel, a pull upon the scar transmits a sufficient amount of stimulus to the muscle on the other side of the scar for the contraction to be continued. Besides this, there are definite electric currents, called electric action currents or waves which have already been referred to. With delicate measurements electric currents can be found wherever there is muscle movement, wherever there is injury to the living tissue, or marked function. The action currents from peristalsis precede the waves of peristalsis and probably are as important a factor in stimulating peristaltic contraction as the mechanical stimulation from a wave that has already begun. They have been demonstrated by R. S. Lillie, and probably have to do with the movement of cilia in ciliated epithelium. In excised segments of the ureter, Alvarez has found that the rate of rhythmic contraction is usually faster in the piece removed from near the kidney than in sections removed from near the bladder, though this is not constant. The evidence that segments of muscle from the duodenum contract at about twice the rate of those from the ileum, seems to show quite definitely that the muscle of the duodenum is more active than that of the lower ileum.

There is, according to Alvarez, a somewhat similar gradient in the stomach, the rhythmic contraction being fastest along the lesser curvature near the esophagus. In the colon the rate of contraction is very slow. These gradients of contraction are definite, and that they have a definite direction can be proven by reversing a segment of the bowel. If, in a dog, a loop of upper ileum a foot long is severed at both ends, leaving the mesentery attached, and the distal end of this segment is sutured to the upper (oral) end of the bowel and the oral end of the segment to the lower end of the bowel, peristalsis will continue, though if solid food is given obstruction will result because of the collision of the waves of the reversed segment with the normal waves of the intestine above. Fluids, however, can usually be forced through for a while.

The muscle of the upper jejunum can be easily demonstrated experimentally by dividing the upper jejunum in a dog. The first action is a sharp contraction at the point of division, then the longitudinal muscle fibers act strongly and turn back a marked cuff, exposing the mucosa on the cuff

sometimes for a distance of a centimeter or more. This turning back of a cuff in the lower ileum is much less marked.

Alvarez has found that the pulling force exerted by a small balloon inserted in the jejunum is much greater than in the ileum, and to a large extent is graduated from the duodenum to the cecum. Naturally, when a muscle acts more rapidly the metabolism is increased, so that Alvarez has found that the metabolism of muscle from the upper jejunum is greater than from the lower ileum. This, too, is in keeping with the anatomical fact that the blood supply for the upper small bowel is greater than for the lower small bowel. The metabolism is usually greater when the blood supply is greater. Where there is metabolism a certain amount of electricity is generated, and this is more evident in rapid metabolism than in slower metabolism. The current recedes in the tissue from the more rapid portion to the less rapid, so that the tissues of the more active metabolism are electronegative.

As for the tone of the muscle, the section of a duodenum or upper jejunum from an animal contracts very markedly; the formation of cuffs after section of the upper jejunum has already been described. Though Alvarez has shown very clearly that the movement of the muscular coat of the upper small intestine is at a more rapid rate and apparently more vigorous than in the lower small intestine, and independent of the nerves, it is also true that there is a difference in the anatomic structure of the nerves, as in Auerbach's plexus, in the upper small intestine and in the lower small intestine.

According to Alvarez, in order to appreciate the gradients in the stomach it is necessary to consider the embryologic derivation of the stomach. In the early stages the stomach, which is part of the digestive tube, is merely a slight oblong dilatation. It then begins to dilate posteriorly, as described in the section on embryology, so that the anterior part represents the wall of the original digestive tube. Later the posterior border, which becomes a pouch and forms the greater curvature, rotates to the left. We find along the lesser curvature loops of muscle fibers which, when contracted, make a gutter, the canalis gastricus. In some of the ruminant animals, as the kangaroo, this may form an actual tube and serve to conduct fluids from the cardiac portion of the stomach to the pylorus. There is a marked difference in the rhythmic contraction of different portions of the stomach. The muscle from the lesser curvature near the cardiac end shows the greatest tendency to rhythmic contraction, the rate being about eleven per minute. Strips from the pyloric portion of the stomach within the greater curvature are very slow in contraction, and sometimes appear not to contract at all. An incision into the muscle of the lesser curvature becomes wide because of the rapid contraction of the muscle that is divided. Along the greater curvature there is but little contraction. There is also a difference in the irritability of the muscle at different portions of the stomach, that near the cardiac end of the lesser curvature being more irritable and having quicker response.

The whole stomach shows less irritability than the bowel. The pyloric ring or sphincter is very irritable, and has a shorter latent period than the

antrum. The duodenum responds more promptly to the galvanic current, though the difference is not so marked. The antrum muscle relaxes rather promptly. The muscle in the pyloric portion of the stomach has frequent violent peristalsis, whereas the muscle in the cardiac portion tends to remain chronically contracted; and the reaction fits in with the function. In a diseased animal there is often very little difference in the rate of contraction of the gastric muscles in different portions of the stomach, and the rate is slower than in the healthy animal.

Alvarez regards the muscle of the cardiac portion of the stomach along the lesser curvature near the esophageal region as practically a pacemaker. Cannon has shown that the origin of the gastric peristaltic wave has no definite seat but that it is more likely to occur where a certain balance is struck between the internal tension of the stomach and the tone of the muscle. Alvarez believes that peristaltic rushes, which seem to begin in the lower ileum, really may occur as a ripple starting in the duodenum, and that somewhat the same thing occurs in the stomach. He thinks the ripples, which eventually result in peristaltic waves, actually arise in the pace-making region at the cardiac end of the lesser curvature.

**Clinical Applications of the Gradient Theory.**—The muscle at the cardiac end of the stomach is more sensitive to adverse conditions, such as the toxins of disease and trauma, than the muscle at the pyloric end. In this way the gradient may be upset. Ulcers at the pyloric end increase the irritability of the pylorus and sometimes cause reverse peristalsis.

A small ulcer on the lesser curvature of the stomach sometimes alters the rate of conduction so that a wave which had begun in the cardiac region is interfered with and the two portions of the waves do not reach the pylorus at the same time. Due to this unharmonious action the stomach may not empty satisfactorily even though the pylorus is open, because one part of the wave may really tend to block the other part which has been delayed. This has a practical bearing, because it has been noted that a V-shaped incision along the lesser curvature often makes a discordant peristalsis, with more functional trouble in the stomach than when there is a complete sleeve resection.

It is important to recognize the fact that the lesser curvature remains the original tube. It is far more important, not only as a regulator of peristalsis, but as the site of the canalis gastricus, than the greater curvature, and in operations on the stomach the lesser curvature should be accurately approximated and kept in line, no matter how irregular may be the greater curvature.

The pyloric sphincter not infrequently has marked spasm even when the lesion causing the spasm is at a distant portion of the stomach or farther down in the bowel. This doubtless is due to the greater irritability of the sphincter as compared with the adjoining muscles, so that with the lowered threshold it responds to stimuli that elsewhere are ineffective. It is well known that in ulcer of the duodenum, inflammation of the gall-bladder or peritoneal lesions of the upper portion of the abdomen, the whole stomach becomes extremely irritable.

Alvarez has called attention to the work by Lillie, who has shown that trauma to tissue causes it to become electronegative to the surrounding healthy tissue, and there is an increase in chemical activity. In the bowel a local injury produces electric currents which extend in both directions, and may block the oncoming peristaltic waves or even cause them to be reversed. Inflammation, if it has not gone to the point of tissue destruction, adds to the irritability of the tissue and increases the metabolism and the tone of the smooth muscle. This is readily seen in the contraction of the smooth muscle opposite a gastric or duodenal ulcer, and in the puckering of the duodenal cap or the spasm of the sphincter ani from ulcer or fissure.

Undoubtedly psychic influences act through the extrinsic nerves and may raise the tone of the muscle and so increase the gradient of the upper portion of the gastro-intestinal tract, but apparently it does not affect the rhythmic contraction.

The portion of the intestinal tract that has the most rapid rhythmic contraction and consequently the greatest metabolism, the duodenum and jejunum, are apparently more susceptible to toxic influences than the slower and less irritable muscle of the lower ileum. The cardiac portion of the stomach, and the region around the pace-making segment of the lesser curvature, are likewise more profoundly affected by toxins than the pyloric end. Alvarez thinks that the effect of the toxins may at first be stimulating and that overstimulation increases exhaustion of the muscles having rapid metabolism, but does not materially affect the muscles of low metabolism, such as the ileum and the antrum gastric muscles that have originally a low tone. The difference in the reaction of the muscles in the different parts of the intestinal tract has been demonstrated by Alvarez, by placing segments from different portions of the bowel in warm Locke's solution and, after they were all contracting, the air which had been bubbling through the solution was shut off. This retarded the contractions of the muscles from the duodenum and the upper jejunum very markedly, but did not materially affect the muscle from the ileum. Alvarez thinks that stagnation of food, which is found not infrequently in constitutional diseases, is due to the affection of the muscles in the stomach and upper duodenum and jejunum, so lowering the gradient of the gastro-intestinal tract and making it difficult for the stomach and upper intestines to empty.

Natural stimulation of the upper portion of the gastro-intestinal tract starts peristalsis and digestion. The psychic influence which is exerted through the external nerves is also well known. Taking food under pleasurable conditions increases the tone of the muscles of the stomach and bowel, and in this way tends to increase the gradient in the upper intestinal tract. With the presence of food acting also to increase the gradient, it is naturally found that the second meal not infrequently empties from the stomach more rapidly than the first, as the second tends to maintain the heightened tone of the gastric and upper intestinal muscles. In starvation the tone is increased abnormally, so the first meal is discharged more quickly.

Alvarez suggests that the presence of food with distention in the duodenum

and upper ileum may be responsible for many clinical conditions that are seen. The diarrheas that sometimes occur after gastro-enterostomy when the stomach dumps the food quickly into the small bowel and causes distention and stimulation may be explained in this manner. Also the diarrhea of achlorhydria, manifested in the morning after the bowel is more responsive to stimuli because of the night's rest, may be due to increased stimulation from the imperfect chemical digestion and the abnormal fermentation. In ulcers of the duodenum or pylorus there is often a six-hour residue of the meal in the stomach; occasionally reverse peristaltic waves occur. Frequently this residue is from the blocking of the pylorus because of the muscle spasm from the ulcer. Sometimes the food seems to empty rapidly in these cases for the first few minutes. After that it stagnates. Alvarez explains this by assuming that the hypertonic stomach when distended by food may be able to overcome the back pressure of pyloric spasm from the ulcer because of the general raising of the muscle tone. After the stimulus from the distention of food has partly disappeared the irritating local effect of the ulcer is sufficient to block the pylorus against the less active waves of the cardiac portion of the stomach.

As has been noted before, stimulation by distention of the middle of a loop of intestine initiates waves that pass in both directions. In feeding through a jejunostomy, if food is inserted too rapidly and distention occurs rather quickly these waves may be carried to the stomach and a sensation of nausea or vomiting produced.

It is well known that obstruction seems to occur more readily in the upper small bowel than in the lower small intestine or in the colon, and the clinical symptoms are much more severe. This appears contradictory when viewed from the standpoint of the greater muscular activity of the upper intestinal tract. There is, however, also greater irritability and the same lesion will produce stronger and more rapid contractions in the upper jejunum than in the lower ileum. Consequently a lesion in the upper jejunum will send out reverse peristaltic waves and cause a contraction in this neighborhood, whereas the same lesion in the lower ileum will cause fewer waves and slighter contraction. In view of the opportunity of overstimulation of the upper jejunum, Alvarez thinks that the muscle of this bowel probably wears itself out more readily from supersensitiveness, although the muscular power may be actually stronger; whereas in the lower ileum the more phlegmatic disposition of the muscle with less sensitiveness to stimulation causes fewer contraction waves with less tendency to obstruction from reverse peristalsis or excessive contraction of the muscle. This is a very important point because it is a phenomenon well known in surgery that the lumen of the bowel must be much more widely open after an anastomosis in the upper jejunum than would be necessary in the lower ileum or the colon. There are other things concerning the gravity of high intestinal obstruction which are discussed in the chapter on obstruction.

That irritation of the lower portion of the gastro-intestinal tract may interfere with the emptying of the stomach is well shown in many cases of

appendicitis. As we know, the discharge of the stomach contents will produce an emptying of the lower ileum into the cecum and so the irritation of the terminal ileum or cecum, as from appendicitis, not infrequently raises the tone and gradient of the terminal ileum, retards the emptying of the stomach, and may cause vomiting. In some patients whose upper gradient is high, this irritation will not be sufficient to interfere with the emptying of the stomach.

According to Alvarez, constipation is due probably more to increased tone in the rectum and sigmoid than to an atonic condition. He thinks that in most cases of diarrhea the left half of the colon and the rectum are atonic, whereas in constipation the tone of the sphincter and of the rectal wall is increased.

Normally, reverse peristalsis seldom occurs in the stomach, but it is a physiologic condition in the upper duodenum. Toward the end of a meal the contents of the duodenal cap are usually forced into the stomach because of the relaxation of the pyloric sphincter which occurs while the part of the duodenum just beyond the cap is still contracted. In this way bile goes into the stomach, but under natural conditions creates no symptoms. Normally, also, there is reverse peristalsis in the right half of the colon. There are occasional instances on record in which the contents of an enema have found their way to the duodenum and even to the stomach.

## VOMITING

The exact mechanism of vomiting has not been definitely determined by the physiologists. It is undoubtedly true that there are different types of vomiting, and that nausea usually precedes vomiting except in the type due to cerebral disease. According to Alvarez, there often appears to be a marked rise in tone of the upper small intestine just before vomiting. The fact that bile appears in the vomited material is sometimes erroneously attributed as the cause of vomiting. This is merely the result of the regurgitation into the stomach, which has been brought about by increased tone of the terminal duodenum.

It is well known that vomiting is produced by many different causes. Toxic material seems to effect relaxation of the cardiac portion of the stomach more readily than of the pyloric portion, and a reversal of the gradient of peristalsis apparently has much to do with many cases of vomiting. In inflammation of the lower bowels from pelvic disease in women or in pregnancy, the accompanying hyperemia to the colon and the lower small bowel and the consequent greater activity of metabolism and increased tone of contraction may readily cause reversal of the gradient with a reversal of the peristaltic waves. It has long been a clinical observation that when vomiting occurs after a diarrhea is well established, the diarrhea often ceases, at least temporarily. In the initial stages of inflammation, however, the most marked inflammatory area is often found in the upper small intestine. The

stomach may reject material that causes marked immediate irritation, but when the irritation is very slight, or when it develops as a result of further chemical changes, often the maximum amount of irritation is not attained until the material has reached the upper small intestine. In this way, then, increased waves of peristalsis will be started from this point, which may produce diarrhea by the waves proceeding downward and vomiting by the waves proceeding upward.

Hatcher, in an excellent review of the mechanism of vomiting, shows that the vomiting center is probably not so important in the act of vomiting as is usually supposed. In fact, many physiologists appear to doubt the actual existence of a special center for vomiting. Whether vomiting is possible without the abdominal muscles has been questioned. It seems to be generally agreed that just before vomiting there is relaxation of the cardiac portion of the stomach with closure of the pyloric end. The circular muscle of the cardiac portion of the stomach becomes flaccid, so that the slightest movement of the abdomen causes a change in the shape of the fundus. According to Cannon, a deep constriction begins below the cardia and sweeps over the antrum of the stomach. This is followed by other waves, and while the waves pass over the antrum the fundus is relaxed. There is then flattening of the diaphragm and quick action of the abdominal muscles, accompanied at the same time by the opening of the cardiac orifice. The contents of the stomach are forced into the esophagus, and by the continued contraction of the abdominal muscles are expelled through the mouth. The vomited material that remains in the mouth is swallowed, and that in the throat and esophagus quickly passes down into the stomach by normal peristalsis.

Cannon noted a distinct antiperistalsis in the stomach only once during vomiting, and this was in an observation of a cat. The question of antiperistalsis in the stomach during vomiting has not been definitely settled. It does occur in the lower forms of animals and possibly in infants. The cardiac sphincter apparently opens through reflex stimulation of an area of the pharynx and the upper part of the esophagus. The path of this reflex is through the glossopharyngeal and the vagus nerves, and the efferent path is chiefly through the vagus, though partly through the ninth nerve.

Eggleston and Hatcher have observed the typical vomiting movements with expulsion of frothy mucus from the esophagus when apomorphin was given to dogs after the stomach and intestines had been excised. Cats and dogs vomit with great difficulty when they are lying on the back.

Hatcher and Weiss think no single movement and no inhibition concerned with emesis is peculiar to vomiting. Probably that portion of the central nervous system which appears to be essential for vomiting merely coördinates the various movements and inhibitions for vomiting, such as the contraction of the pyloric portion of the stomach with relaxation of the fundus and cardiac portion, the inhibition of the esophagus and the closure of the glottis along with the inhibition of respiration, the stimulation of the diaphragm and contraction of the abdominal muscles.

Emetics undoubtedly act in different ways, and there are many reflex

causes of vomiting, such as irritation of the uterus, kidney, bladder, brain, and the semicircular canals as well as from the gastro-intestinal tract. Weiss and Hatcher find such emetics as tartar emetic cause vomiting after intravenous injection by action on the heart. Dividing the spinal cord does not affect the emetic action of small doses of tartar emetic because the impulse produced by it in the heart and the stomach goes through the vagi.

Emetics may produce vomiting according to different physiologic actions. Thus, apomorphin, morphin and picrotoxin may cause vomiting by the cerebral excitation of the regions that concern vomiting, whereas vomiting impulses may be produced by irritation of the gastro-intestinal tract from drugs, such as mercuric chlorid. Such emetics as econotin and emetin act in both ways. Hatcher and Weiss think that the heart is frequently the seat of a vomiting reflex which is produced by disease. Vomiting may be induced reflexly by irritation of the cerebral center, while the heart is the common seat of the vomiting reflex which is caused by poison. The vomiting center, however, must be made hyperexcitable by certain normal constituents of the body.

Herrick points out that the epigastric pain, nausea and vomiting occurring so often in cases of thrombosis of the coronary artery are not infrequently ascribed to some abdominal lesion, as acute pancreatitis or perforation either of a gastric ulcer or of the gall-bladder.

## REGURGITATION, HEART-BURN, BELCHING

Regurgitation is a term used when the gastric contents flow easily into the mouth and when the voluntary muscles of the abdomen and thorax are not concerned in the expulsion of the gastric contents. Regurgitation is effected by contractions of the stomach, bowel, and esophagus. It may be seen in infants when they are "upset" by food, and it is rather frequent in hysterical women. It often accompanies some irritation in the intestinal tract or in the abdominal cavity. Even with good digestion, certain foods, such as onions and fats, may cause regurgitation, and the patient may complain of tasting the food some hours after it has been eaten.

Fats tend to retard the activity of the stomach, both as to secretion and peristalsis, while they stimulate the bowel. This may account for the ease with which fats tend to regurgitate. The same foods that cause regurgitation in small amounts may induce vomiting when taken in large quantities. Heart-burn, really a symptom of regurgitation, is a frequent accompaniment. That regurgitation follows the ingestion of certain foods and that it is found frequently in pregnant women, seems to show that it is due, at least in part, to a type of reversal of peristalsis. Regurgitation also occurs frequently in intestinal colic when there is irritation about the colon or appendix.

Heart-burn, according to Alvarez, is due to regurgitation of the gastric contents and not to excessive acidity. Tests have shown that in many instances the fluid regurgitated and supposed to be excessively acid is below the normal acidity of the gastric juice. Experiments have been made showing that in individuals who have heart-burn the fluid in the esophagus is usually

acid, whereas in normal persons it is alkaline. The irritation of an acid in the esophagus normally accustomed to alkaline contents probably produces the symptoms of heart-burn. When regurgitation occurs after a full meal the first portion of regurgitated fluid is often sweetish in taste; later when the stomach is about empty it becomes very acid, and it is in such cases that heart-burn is frequent. When the stomach is full the upper layers are unmixed with the gastric juice for some time, and this regurgitated material does not give the acid effect of regurgitated material occurring later when the gastric juice is well mixed with the food.

Heart-burn is almost always associated with belching and regurgitation, and though the regurgitated fluid may not apparently reach the mouth in some cases of heart-burn, it comes up sufficiently far in the esophagus to produce the symptoms of discomfort in the upper thorax. Alkalies sometimes relieve it because the alkalies seem to lessen the peristalsis of the stomach and make the contractions more orderly and regular. It also may help by neutralizing the acid contents that have already been extruded into the esophagus.

The diseases that cause regurgitation naturally may produce heart-burn. Not infrequently dentists have observed in individuals with heart-burn that the rear teeth are apparently affected by acid. This is particularly noticeable in pregnant women who suffer from regurgitation and heart-burn.

Belching is doubtless partly due to habit and partly to irregular peristalsis in the stomach. The taking of alkalies often produces marked relief, partly by creating a large amount of gas and partly by quieting peristalsis.

## NAUSEA, COATED TONGUE, HICCUP, BILIOUSNESS

Nausea may be produced reflexly by many different types of lesions, or it may be caused by poisons or toxins, as has been noted in vomiting. Alvarez believes that nausea is usually due to a mild reversal of peristalsis. He thinks that the nausea and possibly the vomiting of pregnancy is from this, as the gradient in the lower part of the intestinal tract is raised because of the accompanying hyperemia and its consequent increase in metabolism and tone of the intestinal muscles. Nausea is frequently felt as coming in ascending waves, which may mean waves of reverse peristalsis. Vomiting from cerebral lesions is usually unaccompanied by nausea, so it seems that nausea probably originates primarily in the intestine, and when it is caused by emetics doubtless it is initiated by the tendency of the emetics to reverse the gradient in the bowel. Nausea occurring with constipation is relieved after emptying the rectum. Nausea after taking large enemas also seems to indicate that it is due to reverse peristalsis. The nausea of an empty stomach can be similarly explained, for food usually induces peristalsis.

A coated tongue and foul breath, according to Alvarez, appear to be due to the same conditions that cause regurgitation. As has been shown in discussing regurgitation, material from the stomach may be regurgitated, and not

infrequently the contents of the small bowel passes through the stomach and into the esophagus and pharynx.

In intestinal obstruction, in marked constipation and in so-called biliousness when the bowels have not moved, a coated tongue and a bad breath are in all probability a result of regurgitation, caused by a reverse peristalsis of the intestine and the stomach. The coating of the tongue is merely a soiling of the tongue in this way. Of course there are other things that may produce a coating of the tongue, such as suppuration in the mouth, or in the nose and sinuses, but the histologic structure of the tongue shows there are no secreting glands that act in sympathy with the stomach to cause a coating, as has been supposed.

A feeling of fullness in the stomach is doubtless due to irregular peristalsis, which is either unharmonious or reversed and causes the intestinal tract to refuse to take more food. The globus, or lump in the throat, is from irregular peristaltic waves in the esophagus, or possibly from an ascending wave meeting a descending wave.

Hiccup, according to Alvarez, may be induced by action of electric currents in the lower part of the esophagus and the stomach being distributed in the diaphragm, causing contraction of the phrenic nerves. Of course this is only one of the numerous causes of hiccups. Undoubtedly it may be due to toxic conditions, which cause a reflex contraction through the phrenic nerves.

So-called biliousness, which has been ascribed to hepatic insufficiency, is not due to such a cause. It is well known that bile normally is found in the stomach, and as has already been pointed out, toward the end of a meal regurgitation of the upper duodenal contents into the stomach is normal. This always includes some bile. The relief of so-called biliousness by purgation is due not to decrease of toxins or increase in the liver secretion, but to the fact that the gradient of the intestinal tract is corrected by stimulation of contractions in the upper portion from the irritation of the purgative.

## VAGOTONIA

The advocates of the current theories of vagotonia and sympathicotonia, which were in considerable vogue a few years ago but are less popular now, may object to some of these interpretations. The doctrine of vagotonia, however, is based on an erroneous conception of the embryology and anatomy of the sympathetic system. As has been pointed out, the most recent work on physiology seems to show that both motor and inhibitory fibers go to the stomach through the vagi and also through the splanchnics. The idea of having two systems of nerves directly antagonistic and clearly marked is not in keeping with the recent facts of anatomy and physiology. The assumption of the undue importance of the ganglia of the sympathetic system has been partly responsible for this. The vagus is a very complex nerve, transmitting many different types of nerve fibers, some of which are medullated, some non-medullated, and of various sizes. Some of the fibers

are afferent and some efferent, some are sympathetic, and many of them are sensory (Alvarez).

Gaskell seems to have shown that the involuntary nerves and ganglia are a definite part of the central nervous system, and are developed from the same embryonic cells as the central nervous system. The chief difference seems to be that the motor ganglia found in the voluntary system in the anterior horns of the spinal cord have migrated in the involuntary system to the paravertebral ganglia, to the solar plexus, or to Auerbach's plexus. There are no commisural fibers between the different sets of sympathetic ganglia, and the movements of the involuntary muscles connected with these ganglia are rather crude, poorly coördinated movements which are accomplished for the most part *en masse*. As for the sensory fibers, the afferent sensory fibers in the sympathetic nerves and spinal nerves both go to the sensory nerves in the spinal cord. The nerves, then, are merely to conduct impulses and to coördinate them, and not to initiate movements within the ganglia. The vagus nerves undoubtedly convey a feeling of hunger or of fullness from the stomach to the brain, and assist in adjusting the tone of the stomach muscles to the food as it goes down the esophagus. They also carry stimuli from the brain that have to do with the secretion of the gastric juice. They doubtless have other sensory functions, but much of the function that has been attributed these nerves is probably myogenic.

## THE SECRETION OF THE STOMACH

Pavlov's work on the stomach has thrown much light upon the character of its secretion. More recently Carlson has investigated the gastric secretion in persons on whom, on account of esophageal stricture, gastrotomy was done. The work of Pavlov, and later of Carlson, has established many new and interesting facts about the secretion of the stomach.

The normal gastric juice is a rather thin, nearly colorless liquid, with a strong odor and an acid reaction. The specific gravity is never very high, usually about 1.007. There are often some protein, mucin, and inorganic salts in the gastric juice, but the essential constituents are hydrochloric acid and pepsin. Renin and lipase, classified as enzymes, are also usually found in the gastric juice.

According to Carlson the acidity in normal gastric juice may vary from a small amount of acid to a half of one per cent. The antiseptic property of gastric juice is due chiefly to its acid. Pepsin acts only in an acid medium and the chief action is upon the proteins. The first result of the action of the gastric juice on protein is to convert it into acid albumin. This is largely the result of the hydrochloric acid, though pepsin aids. Further action upon the acid albumin, or syntonin, produces a number of bodies which are called primary proteoses (or albumoses), and with the continued action of the gastric juice, especially of pepsin, a further hydrolysis occurs in the formation of secondary proteoses. These secondary proteoses are much more

soluble than the primary. With continued hydrolysis peptones are formed. The peptones are the most soluble of the products and are not coagulated by heat. This end result of digestion by the gastric juice is the gradual changing of protein into a very soluble peptone.

Renin is supposed by many to be a modification of pepsin, and is found particularly in the calf's stomach. It produces rapid curdling of milk. Renin and pepsin are supposed to be secreted by the chief or central cells of the gastric tubules, the acid coming from the parietal cells. Apparently the action of renin is confined to milk. Renin is found in other tissues than the gastric mucosa, in many organs and in the tissues of many plants.

Apparently fat does not undergo any true digestive change in the stomach.

Ingested food at first remains almost stationary in the cardiac portion of the stomach, and during this time before it is impregnated thoroughly with the gastric juice the action of ptyalin on starch is continuous. Sugar is formed until the food is well mixed with gastric juice and the reaction is acid. Ptyalin acts in an alkaline or a neutral medium, but not in an acid medium.

The absorption from the stomach is limited. Very little water is absorbed from the stomach. Alcohol seems to be taken up fairly readily by the stomach. A small amount of sugar when rather highly concentrated may be absorbed. Fats are not absorbed, as they undergo but little digestive change in the stomach.

The initial secretion of the gastric juice, which is excited by food, is called "appetite gastric juice." This varies in different individuals, but may be large in amount. The first secretion of gastric juice undoubtedly is due to impulses down the vagi, and may be stimulated psychically to some extent, but more strongly from the taste buds of the tongue. There is constant secretion of the gastric juice, which is contrary to the older theory. Carlson has shown that when the stomach is entirely empty secretion of the gastric juice still occurs, though in greatly reduced amount. After food reaches the stomach the secretion of gastric juice is continued. This seems to be due to the presence of the food in the stomach, and as the irritation of the mucosa of the stomach mechanically by inert substances, such as sand or sponge, does not increase the secretion, it is probable that some chemical element in the food accounts for it. The prolonged contact of food with the gastric mucosa is a great stimulant for the secretion of gastric juice.

The acid is secreted from the cardiac portion of the stomach. No acid comes from the pyloric portion whose secretion is alkaline.

Carlson has constructed a chart (Fig. 20) showing a typical curve giving the amount and the rate of secretion of the gastric juice at different periods. This varies in individuals and according to the palatability of the food. It does not appear to be affected by chewing on inert substances. The secretion shown in the chart is highest during the last five-minute period. This is when the dessert was being taken, and the man on whom the experiment was being made was very fond of dessert.

According to Carlson, the total quantity of gastric juice secreted in man in digestion of the average meal consisting of bread, meat, vegetables, coffee,

milk, and dessert, is about 700 c.c. This is subdivided into 200 c.c. in the first hour, 150 c.c. in the second, and 350 c.c. during the third, fourth, and fifth hours.

Fat has a marked inhibiting effect on the secretion of gastric juice. Cream to some extent delays digestion and oil prevents the secretion of gastric juice for some time, even though the rest of the food may be comparatively digestible. The most abundant secretion of gastric juice is when meats are ingested. Partially digested meat proteins also produce much gastric juice.

If the vagi are divided there is none of the secretion of the gastric juice due to psychic effect, but after food has reached the stomach gastric juice is poured out. Carlson has shown that in the normal stomach there is a more or less continuous secretion of gastric juice, though it is much less when the stomach is empty than when there is food. This varies considerably. In one

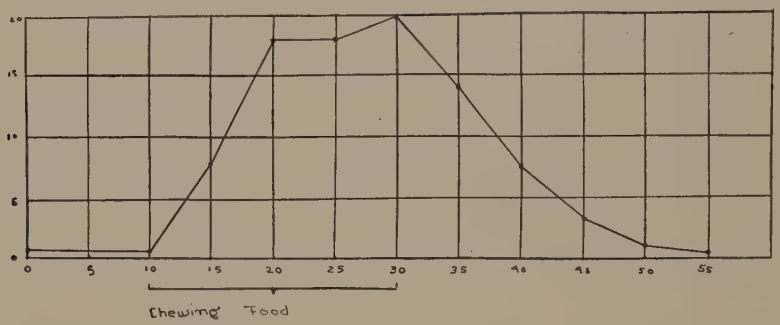


FIG. 20.—TYPICAL CURVE OF SECRETION OF GASTRIC JUICE COLLECTED AT FIVE-MINUTE INTERVALS ON MASTICATION OF PALATABLE FOOD FOR TWENTY MINUTES.

The rise in secretion during the last five minutes of mastication is due to chewing the dessert (fruit), for which the person had great relish. (From Carlson.)

of the subjects of gastrostomy Carlson found that the secretion of gastric juice in an empty stomach varies from 10 to 60 c.c. an hour. If the gastric juice is removed every ten or fifteen minutes, the total secretion for the hour is greater than if removed at longer intervals. Carlson suggests that this may be due to the passage of some of the gastric juice through the pylorus.

Luckhardt and Johnstone found that the continuous secretion of gastric juice is increased during the hypnotic state. It seems probable that an increase also occurs during sleep. This would appear to indicate some inhibitory effect on the gastric glands, possibly coming through the vagi. The seeing, smelling, or the tasting of food induces gastric secretion, and these impulses pass through the vagi because when the nerves are cut psychic influences do not produce gastric juice. Drinking water increases gastric juice.

The latent period of appetite secretion in a dog is four to five minutes, as determined by Pavlov. In man, Carlson has found that the period is short. The rate of appetite secretion of gastric juice varies very greatly, particularly

as to the palatability of the food and the degree of hunger and the appetite. Carlson found that in man the average rate of secretion of appetite gastric juice was about 3.5 c.c. per minute, the lowest being 1.5 c.c. per minute, and the highest 11 c.c. per minute. The quality of the gastric juice depends on the rate of secretion, and appears to be independent of the character of the food.

The importance of appetite gastric juice has been doubtless exaggerated. After section of both vagi in dogs, the digestion does not seem to be seriously impaired. Carlson has removed in man all the appetite gastric juice which is produced by normal mastication of a meal, without impairing digestion or delaying the emptying of the stomach. As the stomach continuously secretes gastric juice it contains a sufficient supply to initiate digestion. Doubtless appetite gastric juice has some beneficent function, and it would not be desirable to dispense with it indefinitely; but the value of gastric juice has usually been unduly magnified.

Edkins in 1906 described a harmone or a specific gastric secretogogue, gastrin, which he claimed to have found in the mucosa of the pyloric region of the stomach. According to Edkins, some substances either in the food or developed in the process of gastric digestion act upon the pyloric mucosa in such a way that gastrin is produced, absorbed in the blood and through the blood acts on the fundic glands of the stomach. This work has been carefully repeated by Ivy and other similar experiments have been done which failed to sustain the findings of Edkins. Ivy has reported that gastric juice, weak hydrochloric acid, dextrose, peptone, fresh meat extract, and Liebig's meat extract when kept in constant contact with the pyloric mucosa for an hour or more had no effect on the gastric glands. Ivy has shown that while this was done the pyloric mucosa appeared to function normally in other respects, as to secretion and absorption.

Luckhardt has recently shown that the gastrin of Edkins is not a specific for the fundic glands of the stomach, because it stimulates both the stomach and the pancreas, whereas the pancreatic secretin of Bayliss and Starling also stimulates the stomach and pancreas. According to Carlson, it seems highly probable that gastrins are artifacts which develop in the decomposition of food or which may be extracted from the gastric mucosa and do not represent a physiological mechanism. They are entirely without effect when given by mouth. The action of gastrins on the stomach is decreased, but not completely checked, by atropin. The gastrins act more effectively when given subcutaneously than intravenously. They appear to be rapidly destroyed by the liver.

Gastrin seems to be a chemical substance resembling somewhat histamin and pilocarpin. According to Carlson, "the gastrin theory may be correct, but all evidence on which it is based appears to have been completely disproved." Gastrins are obtained from a variety of plant and animal tissue by hydrochloric acid extraction, and have been shown to be present in mixed foods of ordinary meals. Increased gastric secretion has been demonstrated by the intravenous injection of watery extracts of strawberry, lettuce, and

spinach. Eisenhardt secured an increased secretion in the stomach of a denervated Pavlov gastric pouch by the subcutaneous injections of extracts of meat, digested bread, extracts of spinach, and normal gastric juice.

The matter of gastrin has been gone into in some detail, because partial gastrectomies for comparatively small ulcers have been based upon the theory that a gastrin in the mucosa of the pyloric portion of the stomach acts specifically in stimulating the normal gastric juice in the fundic glands of the stomach, and that consequently a pylorectomy which removes the pyloric mucosa would decrease the secretion of acid, even though none of the body of the stomach was excised. According to the work of Carlson and others, which has been shown at some length in Carlson's review on the secretion of gastric juice in health and disease, this theory which originated with Edkins seems to have been disproved and can no longer be given as a basis for partial gastrectomy.

Ivy has shown that meat extracts, gastric juice, and hydrochloric acid when introduced into a fistula of the duodenum, increase the secretion of gastric juice after a latent period of about 30 to 45 minutes. Digested meat is without effect. Glucose and oil introduced in such a manner do not increase the secretion of gastric juice, while alcohol, glycerin and spinach extract increase it. Gastric secretion is stimulated by a 10 per cent sodium chlorid solution introduced into the duodenum, but not by soda.

According to Carlson, the pyloric portion of the stomach secretes neither acid nor pepsin. The pyloric secretion is distinctly alkaline, and is not increased by food nor by secretogogues that affect the gastric glands of the cardiac portion of the stomach. Hydrochloric acid and normal gastric juice seem to increase the gastric secretion, acting both in the stomach and in the small intestine. The frequent removal of a continuous secretion appears to stimulate the secretion of the gastric juice.

The effect of salt and of alkalies on the stomach has not been definitely determined. Much of the work along this line has been contradictory. Boyd has found that the alkalies usually stimulate the gastric secretion until a large quantity sufficient to induce nausea and vomiting is given, and then the gastric secretion is repressed. In general terms it seems that soda in a moderate amount increases the gastric secretion. Its effect on the peristalsis of the stomach is probably depressing. The common food condiments have very little or no direct effect on increasing the gastric secretion, though they may affect it through the taste.

The production of mucin in the stomach is largely independent of the secretion of hydrochloric acid. The ferments of the gastric juice, all chemical irritants and mechanical and electrical stimulation increase the secretion of mucin without affecting the gastric juice. In normal men and animals painful stimuli decrease the gastric secretion. Certain pathologic states, however, as pain from gastric or duodenal ulcer, or intestinal obstruction, increase the gastric juice. Pronounced emotions or strong sensations of pleasure seem to cause a depression of the gastric juice, which is also produced by changes in the brain and by fat when applied to the mucous membrane. The action

of drugs on the gastric secretion seems to indicate the preponderance of nervous reflexes in the control of the gastric juice. Confusing elements are sometimes introduced, however, when the drug that affects gastric secretion is at the same time a vasodilator.

There is a distinct antiseptic power in the normal gastric juice probably due to the hydrochloric acid, though this power is usually overestimated and a few bacteria may be found in the normal gastric juice. They are, however, relatively infrequent.

Gastric juice secreted at a rapid rate has a higher acidity than when it is slowly secreted. The total chlorin of a slowly secreted gastric juice is not as low as would be indicated by the low acidity, but there appears also to be a real increase in acidity with the increase in the rate of secretion of gastric juice.

The most important ferment in the gastric juice is pepsin. During the comparative quiescence of the gastric glands, pepsins are stored up in the inactive form of pepsinogen, probably in the granules in the chief cells. Pepsinogen is activated by acids. Lipase is present in pure gastric juice, and appears to be an actual secretion of the gastric glands rather than a product from the blood or lymph, for lipase is in a much higher concentration in gastric juice. This gastric lipase is quickly destroyed by the acidity of normal gastric juice.

The variation of the secretion of gastric juice in normal individuals is quite marked. The fact that complete absence of gastric juice may cause no apparent digestive disorder should be borne in mind. It is possible that there may be some compensatory secretion from the intestines that accounts for this.

**Hypoacidity.**—Achylia gastrica in some cases seems to be congenital and may be hereditary. In many instances bacterial toxins, alcohol, improper food, and possibly other factors cause a decrease of secretion from the gastric glands. Achylia appears to be more common in women than in men. It seems to be due to injury to the gastric glands and not to nervous control. Cancer, wherever located, when advanced is associated with a hyposecretion of gastric juice and with hypoacidity. This is more or less in proportion to the general cachexia and naturally does not appear until the cancer is well advanced. The anemias, primary and secondary, are almost always associated with gastric hypoacidity, and this increases with the progress of the disease. Hypoacidity is often found in disease of the gall-bladder, in chronic colitis, and in marked hypothyroidism.

Hypoacidity appears with pellagra, beriberi, and is probably one of the effects of dietary deficiency diseases when the cachexia is advanced. Dragstedt has shown that the large quantity of fluid, usually alkaline, that is found in dilatation of the stomach is not secreted by the stomach, but comes from the duodenum. It does not seem true that there is really a dilute secretion of the gastric juice, though in intestinal obstruction the toxic amines absorbed from the bowel may cause an increase in the acidity of both the duodenal and the gastric glands. Marked rise in external heat without elevation of

body temperature apparently decreases the gastric secretion and diminishes the acidity. Fever depresses the action of the gastric glands apart from the action of bacterial toxins that may be present. Hypoacidity is usually associated with a rapid emptying of the stomach.

As has been pointed out, it seems probable that the gastrin supposed to be a specific stimulant for the secretion of the gastric juice is not elaborated in the pyloric mucosa, and consequently removal of this portion of the stomach does not lessen the acidity of the gastric juice. In operations in which this seems to be apparent, it is probable that part of the body of the stomach with the fundic glands has been removed. It is also true that such an operation tends to hasten the emptying of the stomach, and consequently shortens the time during which food lies in contact with the gastric mucosa and secretion takes place.

**Hyperacidity.**—According to Carlson, the so-called hyperacidity does not occur. With ulcers of the stomach or duodenum without pyloric obstruction, gastric juice may be at the upper limit of normal or at any point between this and complete achylia. When pyloric obstruction exists, however, there is undoubtedly retention of the gastric contents and the secretory response to the food is prolonged. Consequently, there is excessive gastric secretion. Dragstedt in a series of experiments has shown that in dogs with a subnormal acidity the creation of artificial ulcers seems to increase the acidity, though this does not exceed what in other dogs would be normal. The increase in acidity with gastric or duodenal ulcer is, then, probably due to the irritating effects of the ulcer, instead of the ulcer being due to the increase of acid. The hypersecretion of the gastric juice in ulcer, when there is pyloric obstruction, may also be due to the increased time during which food is retained in the stomach.

Hypersecretion but not hyperacidity of the gastric juice is frequently seen in appendicitis and intestinal adhesions, and is also found in toxic goiter and in certain nervous affections. This, however, must not be confused with hyperacidity, which apparently does not exist. In otherwise normal persons the gastric secretion, according to Carlson, sometimes varies from hypersecretion with the acidity of the upper normal limit, 0.5 per cent, down to complete anacidity, and these variations themselves do not appear to produce disease. The variation from normal is a decreased acidity, which is found associated with cachexia as produced by chronic toxemia from cancer or from the anemias and other causes. There is no disease known which produces a true gastric hyperacidity. The so-called essential hypersecretion (or Reichmann's disease), according to Carlson, does not exist. Hypersecretion may be due, as already explained, to delayed emptying of the stomach from obstruction or to certain types of gastric stasis.

The gastric juice in itself does not produce anatomic or functional disorders except when acting upon tissues that are already abnormal or that have no normal physiologic protection. The importance of gastric juice in the maintenance of health has been greatly exaggerated, whereas the significance of the motility of the stomach has not been fully appreciated.

## SECRETION OF THE SMALL INTESTINE

In the intestine food undergoes its chief change, and absorption is mainly from the intestine. Intestinal digestion begins in the duodenum, and is almost completed when the food arrives at the cecum. There are three chief secretions which affect this digestion—the pancreatic juice, the succus entericus, or secretion from the intestinal glands, and the bile. These secretions are first mixed with the food in the duodenum, and the action continues throughout the small intestine, but is most marked in its upper portion.

The pancreatic secretion is alkaline and as clear as water. It is secreted in a very considerable amount. In man it is supposed to be about 600 c.c. a day. The alkaline reaction is due to the presence of carbonate of sodium. There are three chief digestive ferments or enzymes—trypsin, which is proteolytic enzyme; amylase, a starch enzyme; and lipase or steapsin, a fat-splitting enzyme.

The nerve supply to the pancreas is from the celiac plexus, and through this plexus come the branches from the splanchnics and the vagi nerves. The nerve trunks are supposed to carry both secretory and inhibitory fibers.

The quantity of secretion from the pancreas is dependent to some extent on the character of the food. Bread induces a more abundant flow of pancreatic fluid. However, as Cannon has shown that carbohydrates leave the stomach much sooner than proteins or fats, it may be that this rapid emptying of the stomach has something to do with the stimulation of the pancreas. Proteins stimulate pancreatic secretion, particularly trypsin. Fatty food causes a large amount of lipase. Bayliss and Starling found that acid in the duodenum produces a substance called secretin, probably from the action on prosecretin that seems to be normally present in the mucous membrane of the duodenum. Secretin is not an enzyme, but a type of hormone. It is absorbed in the blood and in this way reaches the pancreas and stimulates the pancreas to active secretion.

Pancreatic secretion seems to be produced in two ways: through the nerves, from the secretory fibers in the vagi and splanchnics, and by secretin, chemical stimulation. Stimulation by nerves alone produces a thick pancreatic juice which is rich in ferments and proteins, but contains little alkali. The chemically stimulated secretion is thin, watery, contains a small amount of ferments or proteins, but is rich in alkali.

Trypsin in the pancreatic juice is probably secreted in a pro-enzyme form called trypsinogen, because pancreatic juice from a fistula has but little action on proteins, but if it is placed in contact with the mucosa of the duodenum or if mixed with an extract from this mucosa, powerful proteolytic properties at once appear. This is probably due to another enzyme called enterokinase. The action of enterokinase is quite prompt.

Trypsin, after it has been activated by the action of enterokinase on trypsinogen, affects protein by hydrolytic cleavage of its molecule, somewhat similar to the action of pepsin. Unlike pepsin, however, it will act in neutral

or alkaline solutions, as well as in slightly acid solutions. Its effect is much more powerful and rapid than the action of pepsin and it carries the digestion of protein further. The preliminary digestive action of pepsin tends to hasten the action of trypsin. Trypsin not only produces results somewhat similar to pepsin in the proteoses and peptones, but acting still further splits the protein molecule into simpler bodies. The character and number of these bodies depend to a large extent upon the amount of trypsin and the time during which it acts. When the action is prolonged the peptone stage is passed and products such as tyrosin, lucin, tryptophan, histidin, and others are formed. Continued action of trypsin produces chiefly amino-acids. The nitrogen of the protein molecules is found in the split products, chiefly as amino-acids, but a small amount of ammonia also appears.

The action of trypsin is augmented and continued by an enzyme called erepsin, which is one of the constituents of the intestine juice, the succus entericus, that is secreted from the crypts of Lieberkühn. Erepsin is found not only in the intestinal mucosa, but it apparently exists in other tissues of the body. It was formerly thought that what might be called the nucleus of the protein molecule is one of the products of intestinal digestion, and this is termed a peptid or polypeptid. The view more generally accepted now is that the continued action of trypsin and erepsin breaks down the protein molecule into what Howell refers to as its original building stones instead of preserving a more complicated constituent, the polypeptid. These building stones are different forms of amino-acids. The tissue cells reconstruct from these simpler products the type of protein best suited to them.

Amylase is the enzyme in the pancreatic juice which acts upon starch and is quite similar to ptyalin. The conversion of starch is eventually into dextrose, and the starch that escapes digestion in the mouth and stomach is mixed with amylase in the duodenum and digestion is probably completed by the time the bowel contents reach the cecum.

Lipase, or steapsin, the fat-splitting ferment, is another of the important enzymes found in the pancreatic juice. It hydrolyzes or saponifies neutral fats. In the former instance the fat is broken up into glycerin and fatty acid. When it saponifies, it forms an emulsion in which the fat is divided into very minute globules. This emulsification is one of the results of the formation of soaps from the fats, as some of the fatty acid which is liberated by splitting the fat into acid and glycerin unites with alkaline salts. This soap is largely instrumental in producing the emulsion of the rest of the neutral fat. It seems probable that fat is not absorbed as such, but is taken up as glycerin and fatty acids by the epithelial cells of the villi and within the cell the fat is again reconstructed. It is thought that lipase has a reverse action and can assist in the reconstruction of fat. The presence of bile greatly augments the action of lipase.

The bile does not contain any definite enzyme that plays a large part in the digestion. Two very important constituents of the bile, however, are glycocholic and taurocholic acids, which are always present in the bile and are chiefly found as salts. The bile pigments, biliverdin and bilirubin,

doubtless arise from hemoglobin. In man about 500 c.c. of bile are secreted in a day. Neither bilirubin nor biliverdin occurs in the feces, but a reduction product, urobilin, is found in the large intestine. The bile pigment is supposed to be reabsorbed, carried back to the liver, and again eliminated. Cholesterin is another important constituent of bile.

With the discharge of chyme from the stomach to the duodenum there is an ejection of bile, so that each entrance of chyme into the duodenum seems to cause an outflow of bile, probably by an inhibition of the sphincter of Oddi, and also by contraction of the gall-bladder. The power of the gall-bladder to contract, however, is not great. The bile in the gall-bladder is usually much more concentrated than in the common duct or in the liver. This is doubtless due to the absorption of water from the bile while it is in the gall-bladder, and also to the possibility of excretion of mucus and cholesterin by the gall-bladder. Formerly a good deal of importance was attached to the antiseptic action of the bile. This, however, is very slight and in many instances probably does not exist at all. Fermentation seems to be more marked in the intestine in the absence of bile. The chief digestive action of the bile in the intestinal tract is in promoting the digestion of fat. This is doubtless due to a combination of the bile salts and the bile acids with the fat, forming an emulsion, and so rendering much better access of lipase to the fat. The bile acids serve as a solvent both for the fats and the fatty acids. The function of bile in promoting digestion is probably indirect, being due to its action upon fat, as has been mentioned, and to the fact that without bile and without the ready solution of fat by the bile acids, fat tends to coat the proteins and carbohydrates and protects them from the digestive enzymes. Fat unmodified by bile also gives a greater opportunity for the development of bacteria.

The intestinal secretion, or succus entericus, which comes from the tubular glands of the intestine, or the crypts of Lieberkühn, is in itself alkaline, due to the presence of sodium carbonate. It contains several very important enzymes together with secretin which is not an enzyme, but a hormone. Secretin is more stable than an enzyme and is secreted from the intestinal mucosa as prosecretin which under the influence of acid becomes secretin. It is absorbed into the blood, and greatly increases the pancreatic secretion and in some instances bile. The most marked stimulant for the secretion of bile, however, is the bile salt itself. Enterokinase has also been referred to and is an enzyme that activates the trypsinogen of the pancreatic juice, converting it into trypsin. Erepsin has an action similar to pepsin or trypsin, but apparently carries the digestion of proteoses and peptones even farther than these other protein-splitting ferments. Erepsin is found not only in the intestinal mucosa, but in other tissues as in the liver, kidney, and pancreas. It seems particularly suited to hydrolyze proteoses and peptones, collaborating with trypsin to take up the stage of digestion of the proteins that has been worked up to by pepsin.

Enzymes for converting disaccharids into monosaccharids also exist. Most of the starches and sugars are absorbed as simple sugars for the double

sugars cannot be used by the tissues. Dextrose is the chief form of simple sugar, but another product of the reduction, lavulose, is also found.

## ABSORPTION FROM THE INTESTINE

Absorption in the small intestine occurs very readily. This process is probably partly due to the chemical action of osmosis and diffusion (imbibition) and also to some vital action by the epithelial cells. Absorption is accomplished in two ways, by the capillaries of the villi through the portal blood circulation and by the lymphatics of the villi, or the lacteals. Formerly too much importance was placed upon the central lacteals. Their action can be observed after a meal containing considerable fat, as they fill the lymphatics and bring them out sharply as white streaks. Carbohydrates after being converted into simple sugars are absorbed chiefly through the capillaries of the villi. The blood sugar is kept rather constant in health at about 0.15 per cent. Dextrose that enters the portal veins goes first to the liver and some of it is stored up as glycogen. The carbohydrates that are not absorbed as sugar may undergo acid fermentation from the bacteria in the intestinal tract, and various kinds of acids are produced such as acetic acid, lactic acid, butyric acid, carbon dioxid, alcohol, etc. If this fermentation is excessive the alkaline reaction of the intestine may be converted into acid and the excessive acids often produce a diarrhea.

Fats are absorbed chiefly by the lacteals. The process probably largely consists in first splitting the fats and then absorption of the split products through the epithelial cells with a synthesis or building up of the fat within the cell which is carried into the lumen of the lacteal. It then goes through the thoracic duct, emptying into the subclavian vein. It is thought that some fat may be absorbed by the leukocytes and excreted by them into the lacteals. The transfer of fat from the epithelial cells of the villi to the lacteals is probably accomplished partly by leukocytes and partly by some function of the lining endothelium. This process is not well understood. A small amount of fat is also absorbed by the capillaries and goes into the liver (Howell). The products of digestion of proteins are chiefly absorbed by the capillaries, though after a large feeding of protein some of its products can be found in the lymphatics. It has been shown by recent workers that amino-acids are found as such in the blood, and after a meal of meat the amount of amino-acids is definitely increased. The amino-acids are distributed to the tissues by the blood and the tissues select and store away a portion of the different amino-acids according to their own needs for metabolism or for repair.

Undoubtedly some digestion goes on in the large intestine, but nothing like the amount that occurs in the small bowel. The secretion of the large bowel contains much mucus and is alkaline in reaction, but it does not contain any distinctive enzymes. While considerable water is absorbed from the small bowel the secretions of the small intestine contain a large amount

of water, so that almost as much water is excreted as one of the constituents of its juices as is absorbed from the food. There is very little secretion by the large intestine, but water is absorbed freely, chiefly in the right colon. Under abnormal conditions doubtless this function can be assumed to some extent by the small intestine.

Bacteria are numerous in the lower ileum, but normally they are infrequent in the upper jejunum. The presence of carbohydrates and the tendency to fermentation by bacteria, thus producing acids, may neutralize the alkaline reaction of the intestinal contents and occasionally may give a slightly acid reaction. This acid reaction is unfavorable to bacteria that attack protein, and consequently may delay or inhibit the putrefaction of proteins if there is an excessive amount of carbohydrate fermentation. The character of the diet is one of the important elements in this change of reaction. In the large intestine the putrefaction of protein is normal and is constant. The reaction in the large intestine is normally alkaline.

Some animals raised under sterile conditions have apparently not been affected by the absence of bacteria in the intestine. Other animals, however, seem to lose weight and vigor under these conditions. Bacteria tend to hydrolyze cellulose and make it useful for nutrition. It is doubtful whether the action of bacteria is necessary and within normal limits whether their products are detrimental to health.

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# CHAPTER IV

## DIAGNOSIS OF DISEASES OF THE STOMACH AND SMALL INTESTINE

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**General Considerations.**—The modern conception of gastro-intestinal physiology has brought about radical changes in our interpretation of symptoms arising from these organs. We are indebted chiefly to Carlson and Alvarez for demonstrating the fallacies and unsupported dogmas of former views on this subject.

As a result of this revision of our ideas covering the basic principles underlying certain gastric disturbances, there has been a definite change in the relative value of many signs and symptoms. There is an even greater tendency towards the so-called systemic conception of disease, such as a correlation of multiple factors in the causation of clinical entities rather than the purely local manifestation at the site of the lesion.

It must be remembered that the stomach and intestines occupy a unique position in the human mechanism. On account of certain anatomic and physiologic relations, the earliest evidences of pathologic changes in other organs are often found in the alimentary system. In the study of patients complaining of gastro-intestinal symptoms, two distinct classes exist; those with actual diseases within the confines of the alimentary tract, and those in whom the symptoms are expressions of disease elsewhere, such as in the heart, lungs, kidney, or nervous system. As pointed out by Head many years ago and later by McKenzie, the manifestations of diseased processes in these organs may so overlap each other as to cause gross errors in diagnosis. Again, the various neuroses of hereditary or acquired origin must be taken into consideration before a definite conclusion can be reached.

In order to minimize the frequency of these mistakes, each patient should be considered as a whole, and, whenever possible, a study of the entire mechanism should be made.

**History.**—In any diagnostic investigation of the gastro-intestinal patient, the anamnesis is the first link in the chain of evidence. Although the physical findings, laboratory studies, and radiological observations are each necessary aids and are often conclusive in themselves, the ultimate interpretation of any digestive condition may be found impossible without the assistance of a careful history. In order, however, that the information obtained from a patient may be of value, it is essential that a prearranged questionnaire be followed and the replies recorded at the time of the interview. These data form the background for further studies and are obtained only by the painstaking and conscientious efforts of one who is trained in the art of history taking.

The most frequent source of error in this part of the examination is the tendency of many, especially the dyspeptic patients, to overemphasize the unimportant features and thus obscure or minimize the real clues in their symptomatology. This danger can be obviated by independent questions tactfully asked in such a way as to guide the patient through the maze of extraneous material to the real pith of the history. It is well at the beginning of the conference to allow the patient to relate the symptoms which are uppermost in his mind before a systematic detailed record is obtained. In this way the individual is put at ease and a sympathetic understanding is established.

The Personal History.—Under this heading should be included the name, age, sex, occupation, and social status of the individual.

*Age and Sex.*—Too much importance should not be ascribed to either age or sex as etiological factors in digestive diseases. Although most of the gastro-intestinal affections in infants and children are due to dietary indiscretions, appendicitis masking under the rôle of acidosis is becoming more generally recognized. Duodenal ulcer, while most common during the third or fourth decades, may occur at any age and in either sex. Carcinoma of the stomach is essentially a disease of later life, yet it is well to remember that there are authenticated records of cases before the age of thirty.

Age and sex have an important bearing on the so-called functional neuroses of the digestive tract. Girls at the stage of puberty and with the recurring menstrual periods, not infrequently complain of vague abdominal discomfort which may simulate organic disease. Following the child-bearing period, visceroptosis with its manifold dyspeptic sequelæ is a common finding and is often associated with other reflex or functional manifestations. The climacteric likewise is prone to be ushered in by digestive disturbances of various types of more or less severity. Heart-burn and gaseous distention are frequently complained of and are usually associated with other evidences of functional disturbances elsewhere in the body. Nervous influences are by no means lacking in the male, as the records during the Great War have demonstrated.

*Occupation and Social Status.*—Vocation has a marked influence on the origin and cause of many digestive disorders. A large number of individuals whose daily routine is spent indoors, are victims of sedentary habits and suffer from the natural consequences of such an existence. Constipation, atony of the stomach and bowels, and perverted digestion are frequent complaints, and probably create a fertile ground for more serious developments. Intensity of mental strain, as found in the student during the examinations or in the business man during a financial crisis, exerts a marked influence on the digestive functions. It is a well-recognized fact that a large number of peptic ulcers are found in this class of individuals. The social status is likewise important in its bearing on the quality and quantity of the food consumed. The rich are prone to eat too much and without due regard to the principles of a balanced diet, while the poor are inclined to suffer from digestive disturbances by reason of the unwise selection of food as well as a necessary

restriction of it. In the industrial fields workers who are brought into direct contact with metals such as lead, arsenic, copper, etc., not infrequently are subject to gastro-intestinal lesions of a varied nature.

The Past History.—A record of all previous illnesses should be carefully noted with the particular emphasis upon any symptoms referable to the gastro-intestinal tract, and inquiry should be made into any digestive disorders occuring during childhood which may prove to be an indication of a chronically diseased appendix or localized abdominal infection. Among the infectious diseases, scarlet fever, articular rheumatism, and diphtheria are the most important in their relation to latent foci of infection.

Following this general survey of records of actual diseases including all focal infections appearing in the patient's history, further inquiry should be made for any isolated or vague but often significant symptoms in the past. This can be best accomplished by taking up each system separately; *e.g.,* the special senses, cardiorespiratory, gastro-intestinal, genito-urinary, and cerebrospinal systems. In this manner a concise but comprehensive analysis of all incidents or infections in the life of the patient can be made and tabulated in a usable form.

Present Illness.—It is highly important that the actual date of onset of the present complaint be obtained. Many patients will attribute their illness to some recent indiscretion in diet when a closer analysis will reveal a history of recurring attacks over a period of several years. The current opinion among laymen that diseases of the stomach and intestines are largely of dietary origin has been a handicap not only in studying the etiology of certain digestive disturbances, but has also delayed rational treatment for many actual organic lesions. It should be remembered that indigestion in its broadest sense implies real pathology much more frequently than it is an indication of a transient dietary excess.

The initial causative factor should always be sought for. The relationship of an acute infection elsewhere in the body should be considered as well as a history of any chronic focus of infection which may coexist. It is not only important that the actual lesion in the gastro-intestinal tract be determined, but an effort should also be made to find the primary cause of this lesion. Following the work of Rosenow in his studies on the selective action of certain bacteria, every focus of infection should be investigated bacteriologically in its relation to coexisting lesions.

Dyspepsia is a term commonly employed to denote any type of digestive disturbance that may occur in the stomach or upper intestines during the progress of the meal through this part of the alimentary tract. Generally the outstanding symptoms are pain, nausea, fullness, regurgitation, or abnormalities of appetite.

**Analysis of Significant Symptoms.**—*Pain.*—In an analysis of the patient's history, pain is by far the most important single symptom. In recording this complaint an effort should be made to determine the exact nature of the pain. Is it sudden or gradual, cramplike, aching, boring, lancinating or merely a painful empty sensation in the epigastrium? Is it affected by

exercise, or movements of the bowels, and does it bear any relationship to meals?

The second step is the location of the pain, and in this connection the patient should be asked to localize as accurately as possible with his finger the exact area. The line of direction which the pain follows also helps in determining its source.

The relationship of food intake to abdominal pain is important, and if a definite history of food relief is obtained, it should carry considerable weight in establishing a diagnosis. However, so-called "hunger pains" are not in themselves pathognomonic of peptic ulcer, as Carlson has pointed out that this sympton may be present in the absence of any demonstrable lesion in the alimentary canal. The writer has shown in an analysis of 162 gall-bladder and gastro-intestinal infections that hunger pains were present in only 50 per cent of peptic ulcers, 15.4 per cent of chronic cholecystitis, and 17.5 per cent of chronic appendicitis. The most probable cause of this symptom is a reflex through the branches of the vagi or a local inflammatory process in the duodenum. The presence of adhesions in the extragastric lesions is undoubtedly a factor, but is not essential to the production of this symptom. According to our experience, the "hunger pain syndrome" has led as often to errors in diagnosis as it has helped in determining the underlying pathology.

In many cases the onset of the pain cannot be ascribed by the patient to the ingestion of either food or drink. This point in itself is of considerable value. Furthermore, the relationship of abdominal pain to other factors besides the intake of food should be sought. Among these factors may be the effect produced by exercise, coughing, posture, or emotional strain. The evacuation of the bowels or bladder, pressure from clothing, or menstrual functions may have at times some bearing on the development of abdominal pain.

**Nausea and Vomiting.**—Alvarez believes that nausea, vomiting, regurgitation, heart-burn, coated tongue, fullness immediately after the beginning of a meal, and at times hiccups, are all due to a mild reverse peristalsis. He has shown experimentally on a man with a jejunal fistula that vomiting was preceded by a marked rise in the tone of the upper bowel. Periods of intestinal activity sometimes tend to force the duodenal contents back into the stomach. This may account for the presence of bile in the vomitus and also the occurrence of fecal vomiting in intestinal obstruction. Vomiting may be produced by over-stimulation of any portion of the bowel, by certain food by-products, localized infections, adhesions, mechanical pressure, or as a purely reflex phenomenon. Nausea ordinarily precedes or accompanies vomiting and is probably caused by reverse peristalsis in the gastro-intestinal tract, and is not controlled by a cerebral center. This would account for cases of projectile vomiting without nausea in patients with brain involvement. Billiousness is probably produced in the same manner, the relief of which is obtained by restoring the normal peristaltic waves rather than by the effect of the purgative on the liver.

In the same manner heart-burn is considered as a regurgitation of food

from the stomach into the pharynx. It does not necessarily indicate a hyperchlorhydria, as in fact recent studies have demonstrated that the regurgitated fluid at times shows a subacidity. Heart-burn occurs often in chronic appendicitis, duodenal ulcer, and gall-bladder diseases. According to Alvarez, it represents in all of these conditions a reverse peristalsis arising near the lesion. (The reader is referred to Chapter III for a fuller discussion of Alvarez' views on the physiology of the gastro-intestinal tract.)

These significant symptoms are not pathognomonic of any single disease, but their presence in a patient's history indicates the existence of some factor which is influencing the normal mechanism of the upper gastro-intestinal tract. Their diagnostic importance is dependent upon other data which will be dealt with under the separate diseases.

Finally, the patient's habits in regard to bowel movements should be scrutinized. The early morning diarrhea of achylia gastrica, the acholic stools of certain bile tract infections, the fatty evacuations of pancreatic diseases, and other well-known syndromes, indicate the importance of a close study along this line.

**Physical Examination.**—The fact that the body generally reacts as a whole to some local infection is sufficient reason for insisting upon a general physical examination in all gastro-intestinal disorders. No details should be omitted, and some definite systematic routine should be followed in making this study. Inaccuracies arising in diagnoses are often due to careless observation or failure to examine all portions of the body. The environment should be conducive to the best possible results. A quiet, well-lighted room and a comfortable examining table are the first essentials. If possible, a secretary or intern should be present to record the physical findings at the time of the examination. The patient should be stripped and a thorough, painstaking tabulation of the condition of each accessible organ should be made.

*Head.*—As the portal of entry to the digestive tract, the mouth and throat bear a close relationship to digestive disorders. The tonsils should not only be inspected, but pressure on crypts should be made for evidence of infection. In suspicious cases suction should be employed. In some instances, the crypts may be free from pus but the irregular, scarred tonsil surface and injection of the anterior pillars are highly suggestive of a latent infection. The teeth should be examined for pyorrhea, and in selected cases x-ray films should be taken for apical abscesses. Absence of necessary teeth or poorly fitting artificial sets give rise to imperfect mastication with its attending ill effects on the digestive tract. A possible nasal obstruction or evidences of sinus infection should not be overlooked. The tongue sometimes gives helpful information, but not to the same extent as formerly believed. The red angry tongue of sprue is characteristic, as likewise the flabby raw-edge seen in pellagral cases. An inflamed geographical type of tongue is found in many dysenteries and also in pernicious anemia.

*Chest.*—In acute abdominal cases the importance of a careful examination of the lungs cannot be overemphasized. There are numerous cases on record of operations being performed for alleged appendicitis when in reality the

pathology was in the chest. Pneumonia and diaphragmatic pleurisy not uncommonly give rise to acute abdominal pain. Circulatory changes, especially following a myocardial insufficiency, tend to produce a chronic passive congestion of the liver and other viscera sufficient to cause discomfort in the abdomen. A study of the heart is therefore indicated.

*Abdomen.*—With the abdominal surface fully exposed, observation should be made for cutaneous evidences of disease. Dilated or tortuous veins indicate some form of portal obstruction. Linea albicantes are sometimes found resulting from loss of weight as well as from previous pregnancies. Lack of muscular support in the abdominal wall is shown by an unusual flabbiness on palpation and by an abnormal bulging in the lower part of the abdomen when the patient is in the erect position. In addition, search should be always made for hernias in the abdominal wall. It is important to note the degree, if any, of distention and to differentiate between the bulging in the flanks due to ascites from the dome-like fullness about the umbilicus which is often characteristic of a cyst or mass.

Palpation naturally follows inspection and frequently serves to verify facts brought out by inspection. Complete muscular relaxation is necessary for a satisfactory examination, and in nervous individuals this end may be attained by directing their attention to some abnormal form of breathing, such as through the mouth. It is advisable to begin the palpation in the left lower quadrant before approaching the more frequent sites of infection. In this manner the confidence of the patient is held and less resistance is encountered. Whenever tumors are felt, their size, surface characteristics, position, mobility, and consistency should be carefully noted.

Rigidity of the abdominal walls furnishes a valuable point, and when not under voluntary control is very definite evidence of peritonitis. Circumscribed rigidity furnishes equally positive informaton suggesting some localized irritation. It should be remembered that pain on pressure does not always indicate pathology directly underneath the palpating hand, as referred pains in the abdomen are not infrequent. It should also be kept in mind that organs are not always found in their usual anatomic positions, which fact is strikingly shown in the wide variations of the site of the appendix. The so-called McBurney point is an unsafe landmark for this common complaint. Abdominal tenderness is a valuable sign, but in neurotic individuals it should be checked by repeated examinations.

Cutaneous hyperesthesia has become an important adjunct in abdominal diagnosis, and when carefully tested and persistently found in a given case, it adds considerable weight to one's final opinion. As generally performed by stroking the abdomen with some sharp-pointed instrument, it is grossly unreliable, but when the degree of hyperesthesia is obtained by pinching the skin, a fairly reliable conclusion may be reached. In some cases a localized hyperesthesia may be present without any appreciable tenderness on palpation.

In addition, a note on the size of the liver and spleen should be made and the degree of patency of the inguinal rings should be determined. No less

important is a systematic examination of the pelvic organs in the female and the prostate in the male.

Percussion of the abdomen is of some assistance to palpation, but its chief value is in differentiating a solid mass such as fluid or tumor from a distended stomach or colon. Auscultation offers little.

**Laboratory Examinations.**—An ordinary examination of the blood is not only important for estimating the general condition of the patient but, also, for diagnosis. There should be a routine study of the hemoglobin, leukocytes, and a different count. If the hemoglobin indicates a definite anemia (below 75) a red cell count should also be made. The Wassermann test should be carried out in all cases.

Should the chemical and microscopical examination of the urine reveal any abnormality of significance, further studies on renal retention should be instituted. The simplest and most practical functional test is the two-hour phenolsulphonephthalein determination. An estimation of the blood urea and creatinine will give further information in cases with renal complications.

Examination of a stool specimen is important, especially with reference to its blood content. A positive test for occult blood in the feces has no significance unless the patient is put on a meat-free diet for two or three days and unless local sources of blood are excluded. On account of the sensitiveness of the benzidine test, the guaiac modification should be used as a check when the former one is positive.

Examination of Gastric Contents.—Owing to the development of the Roentgen-ray examination, the analysis of the gastric contents in surgical conditions has only a secondary value. In skillful hands, however, the information obtained from such a procedure is of considerable importance as much can be determined from this source. Since the small flexible Rehfuss tube has supplanted the former stomach tube, much of the discomfort to the patient has been eliminated and a satisfactory analysis can now be made without difficulty.

The patient is given 50 Gms. of stale bread or one shredded wheat biscuit with 400 c.c. of water. This is taken at a time when the stomach is empty, preferably after a night's fasting. The metal tip of the tube is then placed on the back of the patient's tongue and slowly inserted while the patient is instructed to swallow. Should there be any difficulty in breathing it can usually be overcome by having the patient take a deep inspiration. As a rule the tube can be swallowed more readily when the patient is sitting in a comfortable chair. Ten c.c. samples of gastric contents are withdrawn at fifteen-minute intervals for examination. At the end of the two hours the stomach is usually empty or sufficient data have been obtained to establish the so-called "acid curve." When stasis is suspected a few raisins are given on the previous night and the seeds are searched for in the gastric contents. Each sample is examined for the presence of undigested food, mucus, free hydrochloric acid, total acidity, lactic acid, and blood. A microscopic examination is made for the study of abnormal cells, muscle fibers, sarcinæ, and Oppler Boas bacilli.

The reader is referred to any recent laboratory manual for the details in carrying out these tests.

*Clinical Significance of the Tests.*—The normal amount of fasting contents varies from 10 to 50 c.c. If an appreciable excess is found hypersecretion is probably present. If raisin seed or food are present after a night's fasting gastric stasis is indicated. The gastric contents may be colored yellow or greenish by bile regurgitating from the duodenum. It may be reddish or brownish from blood suggesting ulcer or cancer. In cases of achylia, the contents are usually white with floating particles of undigested bread. Mucus in excess is readily recognized by its ropey viscid appearance and is generally associated with some form of gastritis.

The information obtained from determining the amount of free hydrochloric acid is open to question. Some authors place little reliance upon this test, while others consider it of definite value in the final diagnosis. Recently the fractional method of determination as outlined by Rehfuss has been the object of criticism on account of the inconstant readings. Although it has been shown that the position of the tube in the stomach accounts in a measure for the given reading, the general trend of the acid content as well as a general average of the readings is undoubtedly of value. The average normal figures for free hydrochloric acid are 20 to 50 acidity per cent, although higher readings are not incompatible with good health. In fact there is no amount found in a disease which may not be duplicated in a normal person, and Carlston believes that there is no such thing as a true hyperacidity. Generally speaking, however, an abnormally high percentage of free hydrochloric acid is found in the majority of cases of peptic ulcer.

Of greater diagnostic importance is the absence of free hydrochloric acid in the stomach contents. In the cases of true achylia gastrica there is, of course, no free hydrochloric acid, but there may be a total acidity ranging from 10 to 20 acidity per cent. Although the diagnosis is generally conclusive upon this analysis, it must be remembered that in some instances carcinoma of the stomach may give a similar picture. In the latter condition occult blood is usually present and if there is any appreciable stasis, yeast cells and Oppler Boas bacilli may be found. In this condition lactic acid is also a frequent finding.

The chief difficulty in the interpretation of gastric analyses is due to the variability in the gastric secretion. Hypersecretion may occur as an evidence of a neurosis or it may be a frequent accompaniment of peptic ulcer as well as the diseases of the appendix and gall-bladder. In the latter condition, however, a hyposecretion is more common. Gastric secretion is diminished or absent in acute infections, pulmonary tuberculosis, certain types of neurosis, chronic passage congestion, gastritis, carcinoma, primary anemia and old age. Interpretation of these analyses are, therefore, of value only when considered with the history and other physical findings.

Roentgen-ray Examination of the Stomach.—Only the most important facts in the diagnosis of diseases of the stomach by Roentgen-ray examination will be mentioned.

The reader is referred to special textbooks upon this subject for additional data.

*Methods of Examination.*—The stomach and intestinal tract can be readily visualized by the administration of an opaque meal. This opaque substance is generally buttermilk to which has been added the salts of either bismuth or barium. Bismuth is more expensive and less generally used than the sulphate of barium, although it requires more of the latter substance to produce the same effect. As a rule three ounces of the barium salt is added to twelve ounces of butter-milk for the meal.

The patient is given an ounce of castor oil on the previous night and is not allowed any food on the following morning before the barium is administered. While the milk is being swallowed, the course of the meal is followed by a fluoroscopic examination. All persistent filling defects, peristaltic waves, and rate of progress are noted. As a rule a series of films are taken at this time and the patient is requested to return in six hours for further pictures and observations. At the end of twenty-four hours a final picture is taken in order to determine the rate of progress of the barium through the entire intestinal tract.

Gastroscopy.—The principle of the gastroscope is similar to that of the better known instrument, the cystoscope. Gastroscopy, however, is more difficult and less satisfactory than cystoscopy and, therefore, has a very limited field of diagnosis. The chief difficulties are those of inexperience in technic and physical deformities or defects of the patient. Several forms of gastroscopes are in use, constructed with and without lenses. Its chief field of usefulness is in the diagnosis of strictures and other lesions around the cardiac end of the stomach. This method of examination has been largely supplanted in America by Roentgen-rays supplemented by an actual laparotomy.

Electrogastrograms.—In the study of gastric motility, Alvarez has described an apparatus by which simultaneous mechanical and electrical records of the movements of the stomach and intestines may be obtained. Although this work is still in the experimental stage certain findings may be presented. Both the electric and mechanical records show that many of the waves which seem to begin in the lower third of the stomach really come as shallow ripples from the cardia. The gastric pacemaker is apparently located on the lesser curvature near the esophagus. Stomach records corresponding to electrocardiagrams have been obtained. Coles' findings of gastric movements in the Roentgen examinations have been confirmed on electrogastric records. A close relation between the activity of the pyloric and duodenal end of the stomach has been observed.

**Cardiospasm.**—Cardiospasm is a spasm of the musculature of the cardia producing either partial or complete obstruction to the passage of food into the stomach. This spasm may be transient or it may be maintained sufficiently prolonged to produce actual hypertrophy of the cardiac sphincter. Diffuse dilatation of the esophagus (Fig. 21) frequently follows as a result of this condition.

*Etiology.*—The cause of cardiospasm is unknown, although numerous hypotheses have been advanced to explain its existence. Rosenheim has

suggested a primary atony of the muscular coats of the gullet. Kraus believes the condition is due to the development of a persistent spasm of the cardia associated with paralysis of the circulatory muscles of the esophagus resulting from degenerative changes in the vagi. Meltzer considers it the result of a failure of the central inhibitory nerves to control the contraction of the cardia. Among other causes there may be irritative lesions in the vagi, esophagitis, kinking of the esophagus, or fissures in the cardia (Fig. 43). It may accompany hysteria or be a manifestation of one of the neuroses.

Vinson divides cardiospasm into two groups. In the first group are included cases in which there is a slight sense of obstruction at the cardia to the passage of food, with or without pain, but no roentgenographic evidence of obstruction to the passage of a thick barium acacia mixture.

In the second group the symptoms may be quite as mild as in group one, but there is a definite obstruction at the cardia to the barium meal on roentgenographic examination. In this group the symptoms are usually much more marked than in group one. Patients classified in group one are prone to psychoneurotic tendencies; and although some of them may require forcible dilatation of the cardia to relieve their symptoms, many are relieved by the use of any antispasmodic drugs. Patients in group two do not as a rule exhibit psychoneurotic tendencies, and medical measures are of little value.

*Symptoms.*—The symptoms vary according to the stage of the disease and the degree of esophageal dilatation. The attacks are usually accompanied by dysphagia, pressure and pain under the sternum, vomiting, and epigastric pain.

Dysphagia is the most constant complaint, varying in degree from slight obstruction to complete esophageal closure. In the Mayo series, dysphagia differed from that produced by benign and malignant strictures in that fluids were as likely to give trouble as solids. Apples, popcorn, and cold water seemed to cause the greatest difficulty. Because of the limited intake of food, marked nutritional disturbances occurred, especially during the early stages of the disease. Later, patients acquired methods whereby more food could be forced into the stomach, usually by eating solid food and then drinking several glasses of water in rapid succession. This caused the spasm to relax and allowed the food to pass into the stomach. As a rule, dysphagia is not acutely painful, but there is usually a sensation of fullness beneath the sternum. In Smithies' series there was constant dysphagia in 45 out of 47 cases. This symptom was present *for fluids only in* 21, *for solids only* in 14, and *for all foods* in 12 cases.

Vomiting is a frequent accompaniment and is generally of a sudden, explosive type, occurring shortly after the ingestion of food. The vomitus commonly consists of material similar in appearance to that just eaten. It is alkaline in reaction and has not the characteristic acid odor of gastric contents. In advanced cases, vomiting is delayed and food taken the day before may be returned unchanged.

In the Mayo records, out of 415 cases, 197 had epigastric pain which was the initial complaint in a considerable number, often antedating by several months the onset of dysphagia.

*Diagnosis.*—A tentative diagnosis of cardiospasm can often be made by the history of a long-standing dysphagia. Roentgenographic findings (Fig. 21) and the ability to pass a No. 45 French olive into the stomach on a previously swallowed silk thread, make the diagnosis complete. Carcinoma of the cardiac end of the stomach or diverticulum of the lower pole of the esophagus may lead to some confusion, but can generally be differentiated without difficulty.

FIG. 21.—DIFFUSE DILATATION OF ESOPHAGUS WITH CARDIOSPASM. Treated successfully with atropin.

Verbrycke has mentioned the association of angina pectoris with cardiospasm. On account of the similarity of the pain in both conditions, a close study is necessary to recognize the underlying factors.

**Acute Gastritis.**—*Etiology.*—Acute gastritis is a much abused term which has been employed to cover a multitude of erroneous diseases without reference to any definite pathology. Strictly speaking, the term "acute gastritis" should be confined to a definite clinical and pathological entity where there is an actual inflammation in the mucosa of the stomach. It varies from a mild congestion to a true inflammation, and may be caused by improper food, chemical irritants such as alcohol, drugs, metallic poisons, and infections. Individual suscepti-

bility plays an important part in all of these causes. Coarse, poorly prepared and often infected food will produce symptoms of an acute gastritis in one individual but may be eaten with impunity by another. Contaminated milk is the most common cause in infants. Sea foods often precipitate a violent anaphylactic reaction simulating a true gastritis. Food that has undergone putrefactive changes is prone to cause gastritis. The common household poisons and chemical irritants, such as bichlorid of mercury, arsenic, lye, lysol, etc., produce rapidly acute lesions. Crabee describes four types of chemical gastritis:

1. Chemicals having a fixative effect such as bichlorid of mercury or carbolic acid, which cause a membranous necrosis of the superficial layers of the mucosa.

2. Chemicals having a binding action such as sulphuric, hydrochloric, and nitric acids, producing a pathological picture similar to the foregoing except there is less membranous formation and more direct maceration and necrosis.

3. Chemicals causing a macerative effect, such as alkalies, caustic soda and potash.

4. Milder chemical agents such as carbolic acid, chromic acid, arsenic, etc., which cause a catarrhal hemorrhagic inflammation with erosions.

In phlegmonous gastritis, active bacterial invasion of the tissues takes place. The pyogenic organism usually predominates, the lesion being due to a staphylococcus, streptococcus, or pneumococcus infection.

In membranous gastritis, either the formation of a pseudomembrane appears upon the gastric mucosa or a fibrous exudate may develop. This process may arise from diphtheria in the upper respiratory tract or may be formed after swallowing certain poisons. Very rarely acute gastritis is caused by fungi or parasites.

The so-called toxic gastritis usually accompanying one of the infectious fevers may be caused by one of several factors—fever, septicemia, toxemia, or altered secretory motor functioning of the stomach.

*Symptoms.*—Patients differ greatly in their symptomatic reaction to acute gastritis. The first symptoms are those of fatigue, general malaise, and aching pains in the back, limbs, or head. Later there is loss of appetite, nausea, and vomiting with more or less burning in the epigastrium. In the mild cases, anorexia, nausea, chiefly in the morning, and a dull pain in the stomach are the chief symptoms. In the more severe cases, vomiting is continuous and is associated with fever, prostration, and evidence of shock. The vomitus consists largely of mucus, sometimes tinged with blood, and there is often an intractable diarrhea.

*Diagnosis.*—The diagnosis of acute gastritis is usually apparent from the history of ingestion of decomposed food or other toxic or chemical agents. The rapid relief following the vomiting and the absence of fever differentiate it from the more common upper abdominal infections. The symptoms, however, may closely simulate cholecystitis, appendicitis, pancreatitis or even duodenal perforation. Unless there is an unmistakable history of food or chemical

poisoning immediately prior to onset of symptoms, the diagnosis of acute gastritis should be made only after eliminating all possible inflammatory processes in the abdomen.

**Chronic Gastritis.**—*Etiology.*—Chronic inflammatory changes in the stomach wall may be considered as an end-result of repeated single insults to the mucosa. The same etiologic factors which produce acute gastritis may when frequently repeated, bring about a chronic gastritis. The hurried meals, insufficient mastication, badly prepared foods, excessive use of condiments, certain drugs, and alcoholism, are predominating factors which should be emphasized. The stress and strain of a busy life, the indigestible foods served in the so-called "quick-lunch rooms," and the heavy protein evening meals, are also contributory agents in the production of this disease. Certain drugs when taken over a long period of time, particularly the iodids, bromids, salicylates and many of the narcotics, give rise to gastritis.

Chronic gastritis may be secondary to cardiac, pulmonary, renal and hepatic diseases; in fact, any condition causing a chronic passive congestion in the splanchnic region favors the development of this condition. It is prone to accompany any chronic disease which lowers the resistance of the gastric mucosa, interferes with the secretory functions of the stomach and leads to infection of the mucosa either by the lymphatics or blood stream or through ingestion. A common example of this type is pulmonary tuberculosis. There is also good reason to believe that a chronic bacterial invasion of the stomach may arise from oral sepsis, infected tonsils and sinuses, and inflammatory conditions of the nasopharynx.

*Symptoms.*—The symptoms may begin with an acute gastritis or the onset may be so insidious as to extend over a period of several months. Ordinarily the individual complains of a loss of appetite, coated tongue, offensive breath, and a feeling of distress in his abdomen after meals. Nausea and vomiting, especially in the morning, are frequent complaints, and the bowels are generally constipated. The epigastric discomfort is usually a sensation of heaviness and is associated with considerable gas an hour or so after meals. The vomitus after the meal is considered quite characteristic. Fenwick describes it: "Rather abundant in quantity, it presents the appearance of a slimy mass containing numerous pieces of food which exhibit no sign of digestion. The mucus is uniformly distributed through the ejecta and each particle of meat or bread is completely coated with a viscid material. The amount of acid present is inversely proportional to the amount of mucus, free acid being rarely observed."

*Diagnosis.*—The diagnosis of chronic gastritis must be differentiated from chronic functional disturbances of the stomach, cirrhosis of the liver, tuberculosis, pernicious anemia, and carcinoma of the stomach. The straightforward types of chronic gastritis arising from the use of alcohol, drugs, passive congestion, etc., usually present no difficulty. The atypical forms may simulate any of the foregoing diseases, but as a rule specific tests are available for differential diagnosis.

Chronic gastritis cannot be diagnosed by the Roentgen-ray alone, as the

contour of the organ is not altered. The stomach analysis is a helpful aid because subacidity with an excess of mucus is a characteristic feature.

**Gastrectasis.**—Acute dilatation of the stomach is a fairly frequent observation in young adults and may occur as a medical, surgical, or obstetrical aftermath. The medical cases as a rule occur during convalescence from acute infectious diseases, particularly pneumonia and sometimes after chronic diseases such as nephritis, tuberculosis, and myocarditis. In rare instances the mere overloading of the stomach will produce an acute dilatation.

Postoperative cases are not infrequent, especially following abdominal operations. Chloroform has been the most commonly used narcotic in these cases, and probably is mainly responsible for the production of the dilatation. In obstetrical work, acute gastrectasis occasionally happens, but it is generally when chloroform has been used.

*Etiology.*—The definite cause of acute dilatation of the stomach is not always apparent. As a rule, there is an associated involvement of the duodenum. Borchgrevink believes that the latter condition is brought about by direct pressure of the stomach on the duodenum as it crosses the spine. Dragstedt considers the dilatation as the primary factor and the toxic symptoms as being due to duodenal stricture. Meltzer suggests that the dyspnea with frequent swallowing of air without saliva may be a factor in the production of the dilatation. Fagge's original description of these cases was based upon his observations in a case in which the patient had overeaten and with classical symptoms died in collapse. Connor, of Cincinnati, reported 102 cases of which 42 followed anesthesia. Elsner suggests that in all probability there is an involvement of the innervation leading to dilatation, this in itself causing by traction a constriction of the duodenum.

*Symptomatology.*—The initial symptoms usually suggest some abdominal complication. There is often severe epigastric pain, nausea, and vomiting with marked prostration. The vomitus is largely fluid in character containing little or no hydrochloric acid, but often showing bowel and duodenal secretion. In spite of the persistent vomiting and gastric lavage, the hypersecretion continues in enormous amounts. Dehydration of the tissues is a natural result as shown by early collapse, scanty urine, a rapid pulse and a general decline in the patient's condition.

Acute dilatation occurring in the course of various toxemias, in intestinal stasis, and atony, are much less severe and are usually attended by milder symptoms and less dehydration. This type is essentially an acute atony of the stomach.

The other type is an actual paralysis of the gastric musculature.

*Diagnosis.*—In the physical examination, the abdomen is markedly distended, especially the epigastrium. The outline of the stomach can often be seen and on palpation its borders can generally be made out without difficulty. There are no pathognomonic signs or tests other than the repeated removal of fluid by tube from the stomach. The diagnosis is based on the fact that acute dilatation follows either an acute infectious disease or an operation during which a general anesthetic was used. It must be differentiated from acidosis,

uremia, intestinal obstruction, postanesthetic vomiting and acute pancreatitis. Occasionally tetany occurs as a toxic phenomenon.

**Chronic Dilatation of the Stomach.**—Chronic dilatation of the stomach may be of two types: the atonic, due to paresis or marked weakening of the gastric wall in the absence of any obstructive lesion; and the hypertonic, the most common type, resulting from obstruction at or near the pylorus and is associated with an element of spasm and unusual activity.

*Etiology.*—The atonic type of chronic gastrectasis may continue after recovery from acute infections, as typhoid fever. It is found in association with long-standing exhaustive diseases, such as tuberculosis, malignancy, diabetes, and uremia. Occasionally it is found as a manifestation of degenerative cord lesion and may also occur with various types of insanity. It is thought by some observers that excessive eating and drinking may predispose to this condition.

Frequent causes of the hypertonic type are ulcer of the pylorus and duodenum and malignancy of the pylorus, pylorospasm, partial stenosis from adhesions, gastroptosis, or pressure from the structures adjacent to the pylorus.

*Symptoms.*—Atonic dilatation may give no distinctive symptoms, only a feeling of epigastric distress or recurrent attacks of epigastric discomfort, abdominal pain and copious vomiting.

Hypertonic gastrectasis is usually produced or accompanied by ulcer, malignancy, or adhesions. With the beginning of dilatation there is a feeling of weight in the stomach and depression, frequently accompanied by regurgitation or eructation of gas. After an indefinite period, these symptoms are usually followed by vomiting, the vomited material consisting of large amounts of sour, fermenting contents with fragments of food swallowed sometimes as long as several days before. In cases of long standing, there is apt to be great emaciation owing to the loss of abdominal fat and the increased weight of the stomach producing in addition a gastroptosis. Vigorous peristalsis is seen from time to time which enables one to outline the size and shape of the stomach. Antiperistalsis may sometimes be noticed. When gastrectasis is of but moderate degree, the symptoms of beginning stasis are present, giving rise to the well-known symptoms of an irritable stomach. Patients are generally relieved temporarily by taking soda or other alkalies and also by vomiting.

*Diagnosis.*—Chronic atonic dilatation of the stomach is easily recognized when it is marked. The moderate degrees of dilatation, however, are more common and the diagnosis is not so apparent. The most reliable information is obtained by a roentgenologic examination of an opaque meal. The size and contour of the stomach are thus obtained and often the actual cause of the dilatation may be demonstrated. As most of these patients suffer from a chronic hypersecretion, the stomach tube will usually reveal a copious amount of fluid several hours after a meal.

Sometimes the atonic type is secondary to a general atony following a protracted illness, and it may be looked for in association with the advanced stages of a chronic wasting disease. This group of chronic dyspeptics constitutes a class which drift about from one doctor to another without obtaining

FIG. 22.—FEMALE, AGED 50 YEARS, COMPLAINING OF VAGUE GASTRIC DISTRESS. Gastro-intestinal studies were negative with exception of marked ptosis. (Reproduced by courtesy of Dr. A. L. Gray.)

any permanent relief. In the hypertonic dilatation of the stomach, there are usually the symptoms and signs of the accompanying condition of cancer, ulcer, or other causes of pyloric obstruction.

**Gastroptosis.**—The low position of the stomach as demonstrated roentgenologically by an exaggeration of the fishhook type or of the drain-trap type of stomach, is known as gastroptosis. The pylorus occupies a lower level than normal and the fundus of the stomach is elongated (Fig. 22). It is usually associated with an enteroptosis or a general visceroptosis.

*Etiology.*—Gastroptosis may be congenital or acquired. The former type is more important but is not necessarily productive of symptoms. As a rule some extraneous factor, such as chronic infection, neurosis, or loss of weight precipitates the condition, especially when a congenital predisposition is marked.

Acquired gastroptosis may be due to various factors: first, multiple pregnancies; second, debility induced by undernourishment and wasting diseases; third, increased weight of the stomach contents and adhesions of the stomach or bowel, by cecal or upper intestinal retention, and by enlargement of the liver; fourth, postoperative, due to removal of supporting tissue as development of ventral hernia; fifth, pressure about the diaphragm by intrathoracic growths, spinal curvature, or lordosis.

*Symptoms.*—The symptoms of both types are practically the same. In the congenital form, the patient may go through life without any marked digestive disturbance, but generally some strain, stress or diseases elsewhere in the body will call attention to the existing abnormality.

Three more or less typical syndromes of gastroptosis may be recognized: first, the neurasthenic with general lassitude, weakness, and pain in the back; second, the dyspeptic with headaches, constipation, and anorexia; and third, the circulatory neurosis with fainting, vasomotor instability, throbbing of the abdominal aorta, etc.

*Diagnosis.*—The individual with gastroptosis usually presents a clinical picture which is readily recognized. There is generally the so-called asthenic habitus which is characterized by an elongated shallow thorax, a floating tenth rib and an acute costal angle. As a rule, the epigastric area is markedly flattened in contrast to the abnormal protrusion of the abdomen below the umbilicus. The right kidney is usually ptosed and sometimes the liver and left kidney are lower than normal. Inflation of the stomach with a seidlitz powder or tube will readily show the outline of an elongated and atonic organ. The normal stomach at its upper two-thirds is almost vertical and the lower one-third is nearly horizontal. Although formerly the umbilicus was considered the low limit for the greater curvature in the normal individual, the stomach must now be well below the rim of the pelvis before a diagnosis of gastroptosis is justified. Some clinicians lay considerable stress on the loud splashing in the region of the navel following a series of downward strokes delivered with the tips of the fingers. This sign, of course, is due to the agitation of fluid in the presence of gas, and when found one or two hours after a meal, it generally indicates at least an atonic stomach, but not necessarily a ptosed organ. Glenard emphasized the epigastric pulsation which usually indicated that the stomach had descended, permitting the full impulse of the aorta to reach the palpating hand. Other tests and signs have been suggested, but are of doubtful value. Our chief reliance is upon x-ray studies, which not only give the shape and position of the stomach, but also make it possible to follow accurately its motility.

The stomach may be very low and yet its evacuation time may be normal. It is only in those cases in which there is a disturbance of function that

symptoms of gastroptosis occur. The method of the filling of the stomach from the standpoint of the radiologist, is sometimes a differentiating feature; one type will fill up like a tall cylinder preserving its tone, while another will respond like a flaccid bag, the weight of its contents being concentrated at the point of lowest support. It is particularly in the latter type of stomach that symptoms occur.

**Pylorospasm.**—Pylorospasm is a spasmodic contraction of the pylorus resulting from some gastric or extragastric lesion. It may occur as a pure neurosis, but it is generally due to some form of irritation causing a tonic contraction of the pyloric muscle.

*Etiology.*—The cause of pylorospasm is not definitely known. It is usually associated with gastric or duodenal ulcer, gastroptosis, gall-bladder infection, cancer of the stomach, or other reflex irritation from disease of the stomach or neighboring organs.

There is also a purely functional type which is closely related to clinical conditions known as vagotonia, autonomic imbalance, the hypertonias of infancy, and other motor disturbances of the gastro-intestinal tract. The symptoms are identical and can be differentiated from the organic type only by the process of elimination.

*Symptoms.*—At the height of digestion the pylorus suddenly becomes spasmodically contracted and is accompanied by intense pain in the epigastrium. There is generally nausea and vomiting and a general feeling of distress. In the majority of cases there is a history of recurring attacks, at first infrequent but later becoming more or less continuous. In advanced cases, vomiting brings up food of several days' standing such as is found in gastric dilatation. As this condition progresses, marked emaciation, severe constipation, and loss of strength follow. The reader is referred to the chapter on acute and chronic dilatation of the stomach for a more detailed account of symptoms which are produced by pylorospasm.

*Diagnosis.*—The history is usually significant and often pathognomonic. During an attack the pyloric contraction causes a firm mass in the upper abdomen which is generally palpable, but disappears with the cessation of pain.

The gastric analysis is of little value other than showing evidence of retention. When the attacks are frequent and dilatation exists, stagnation of the stomach contents occurs. Roentgen-ray examination is usually distinctive and often differentiates the two types of pylorospasm. A standard test for excluding the functional spasm from those having an organic basis is furnished by the administration of atropin or belladonna in full doses. A pylorospasm produced by an organic lesion is not relaxed by atropin, but when the spasm is of reflex origin, complete relaxation follows (Figs. 23, 24).

**Pyloric Stenosis.**—*Etiology.*—Pyloric stenosis may result from extrinsic or intrinsic causes. Among the extrinsic factors are compression from neighboring organs and adhesions. Kinking of the pyloric end of the stomach resulting in stenosis may be brought about by change in the anatomic position of the liver, gastroptosis, cancer of the pancreas, gall-bladder and ducts, and involvement of the glands about the hilus. The most frequent extrinsic cause

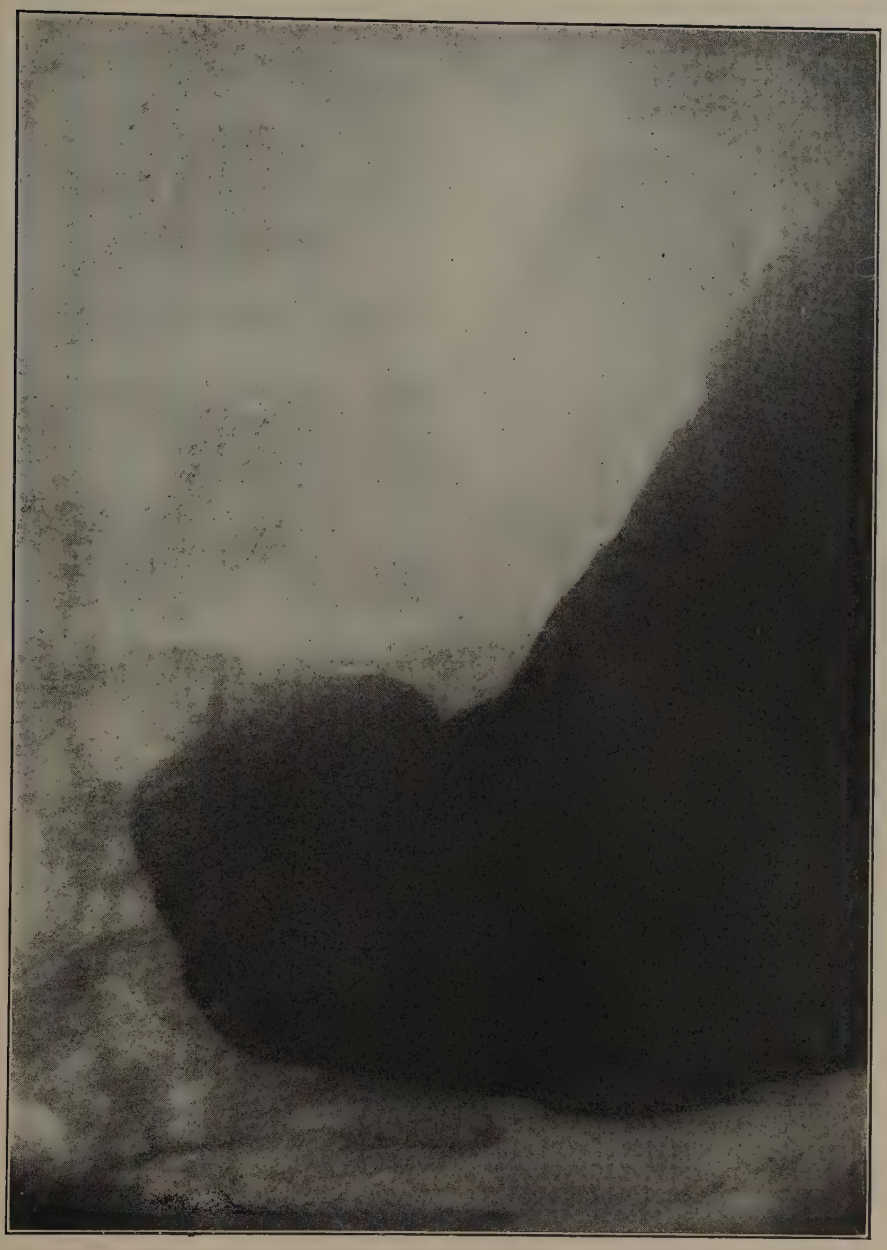

FIG. 23.—PYLOROSPASM BEFORE ATROPIN WAS ADMINISTERED.

arises from adhesions around the pylorus secondary to diseases of the adjacent organs.

The intrinsic factors are the most common causes of pyloric stenosis. Among these, cancer stands first, appearing as an ulcer, infiltration, or vegetative growth. The next most frequent cause is cicatricial tissue as an aftermath of a pyloric or prepyloric ulcer.

*Symptoms.*—The symptoms of pyloric stenosis are dependent largely on the primary cause of the stenosis. Pain is always present except in very mild cases. It varies in intensity and may be intermittent, continuous, or periodic. Vomiting generally brings temporary relief and as a rule is provoked by eating

FIG. 24.—PYLOROSPASM AFTER ATROPIN WAS ADMINISTERED.

heavily. As the condition progresses, dilatation of the stomach develops and the vomited material may show remnants of food eaten several days previously. The systemic effects of pyloric stenosis are usually marked. On account of the inability to supply the body with adequate nourishment, emaciation, anemia, and prostration follow in prompt succession. Dehydration of the tissues is a late manifestation and generally indicates a grave prognosis.

*Diagnosis.*—When malignant disease is the underlying factor, there is usually a history of gastric disturbance, pain and vomiting after meals, and rapid loss of weight. The barium meal will show an irregular filling defect near the pylorus. The stomach will show a residual fluid with a definite reduction in free hydrochloric acid. The fluid is generally brownish colored from the presence of old blood and may resemble coffee grounds.

In the cases of benign stenosis, the constitutional symptoms are less marked, and may occur at any age. The local symptoms, however, are practically the same as found in the malignant type. There is the usual definite gastric retention of fluid; the stomach contents are bland; sarcinæ and yeast cells are often present and there is generally a hyperacidity. The history in these cases is most important and is a valuable adjunct in the differential diagnosis of the various benign causes of stenosis.

The diagnosis of stenosis due to extrinsic causes will depend upon the symptoms of a benign stenosis plus evidences of an associate extragastric lesion. The careful study of the function and size of the neighboring organs is essential, as no diagnosis may be considered conclusive without an exhaustive search for other pathology in the abdomen.

In all cases of obstruction, it is necessary to determine how much of the stenosis is due to organic changes and how much is dependent upon a secondary spasm. The use of atropin in full doses will generally assist in clearing up this point, while the history, physical signs, and x-ray studies will indicate the primary organic basis of the obstruction.

After considering the more common causes of pyloric stenosis, it must be remembered that other less common causes may include syphilis, congenital defects, benign tumors, foreign bodies in the stomach, etc.

**Congenital Pyloric Stenosis.**—The most frequent malformation of the stomach is the so-called congenital pyloric stenosis. It is more common in males and according to some authors, it is more frequent in the artificially fed babies. The average thickness of the wall of the stomach in the infant is from 5 to 10 mm., while the average thickness of the muscle itself is from 4 to 7 mm. The main anomaly exists between the serosa and the subserosa coats.

*Etiology.*—There are two theories as to the cause of congenital pyloric stenosis. The congenital theory is based on the assumption that there is a congenital hypertrophy of the circular muscles of the pylorus. It is known that in the newborn the pylorus is relatively thick and later on becomes thinner. If this thickness persists, stenosis will develop.

According to the neoplastic theory, there is an actual tumor-mass in the nature of a benign adenomyoma which usually is sharply defined and is covered with smooth peritoneum.

*Symptoms.*—The symptoms vary with the stage of the disease and the resistance of the patient. The condition as a rule manifests itself during the first few weeks of life. At this period, the only evidence may be vomiting shortly after nursing. The vomiting may be of the projectile type occurring entirely independent of other symptoms. On account of the vomiting, the

nutrition suffers and the baby rapidly loses in strength and weight. Hunger is marked although at times anorexia may be present. When dilatation occurs the urine becomes diminished, the tissues are dry, pulse is rapid, and the usual signs of dehydration supervene. The epigastrium is prominent, visible peristalsis is seen, and generally a palpable tumor about the size of a walnut is made out in the region of the pylorus.

**Syphilis of the Stomach.**—Although gastric symptoms are frequently found in syphilis, true syphilitic involvement of the stomach is extremely rare.

In 1891 Chiari made an exhaustive review of the literature and was able to accept the evidence of only 7 reported cases as being unmistakably syphilitic. Since the advent of the Wassermann test, Chiari's histologic picture has to a large extent been lost sight of as numerous observers have published an increasing number of case reports in which the serum reaction and clinical history have been the chief diagnostic criteria.

In a most analytic and comprehensive manner Hartwell has recently made a detailed study of all cases reported as gastric syphilis and has found only 23 in which the histologic evidence justifies such a diagnosis. In only one instance were spirochetes definitely demonstrated in the tissues. He showed that "grossly, syphilitic ulcer of the stomach differs in no distinct way from simple gastric ulcer. Neither by its position, its size, nor its outline can it be positively diagnosed with the naked eye. Suggestive factors are its tendency to be large, its irregular serpiginous border, its firm smooth base, and the presence of a demonstrable thickening in the stomach wall at a considerable distance from the ulcer itself. Multiple ulcers are apparently more common than with the nonsyphilitic ulcer." The histologic picture is generally conclusive. Its chief features are perivascular infiltration, a replacement of the mucosa or submucosa with a necrotic layer of granulation tissue, dense fibrous tissue extending into the muscular tunic, and scattered fibroblasts. The blood-vessels are extensively diseased, some showing a simple endarteritis while in other sections hyaline thrombosis with organization is common.

*Symptoms.*—The symptoms of gastric syphilis are not distinctive. In Hartwell's series, neither the pain, the vomiting, hematemesis, nor evidences of perforation were in any way characteristic. Other observers, however, have emphasized certain clinical manifestations which were considered by them more or less typical. *Pain* in the epigastrium is the most frequent single symptom and is present in practically all cases. It is usually severe, becoming more intense after meals and at night. In the early stages the distress may be relieved by food or alkalies, but later in the disease only vomiting gives relief. *Vomiting* is a common complaint and generally occurs immediately after eating. When the lesion is in the body of the stomach, producing an hourglass type, only a small amount of food can be eaten before vomiting takes place. *Emaciation* is unusually rapid and marked. In Bram's series this sign was present in 80 per cent of the cases. *Anemia* is a frequent accompaniment and adds to the gravity of the condition. Other less characteristic symptoms are hematemesis, evidences of stenosis, and general weakness.

*Diagnosis.*—A carcinoma history with corresponding laboratory and roentgenologic findings in a young man who is not particularly ill is the usual picture of gastric syphilis. On account of the atypical history with changeable symptoms, the diagnosis is largely dependent upon objective findings. Although there is considerable doubt in the mind of some observers as to the conclusive evidence obtained from radiographic examinations, Carman has given the following more or less characteristic findings: (1) a filling defect of gastric outline, usually without a corresponding palpable mass; (2) shrinkage of the gastric capacity; (3) stiffness and lessened pliability of the abdominal wall; (4) absence of peristalsis in the involved area; (5) pylorus gaping rather than constricted; (6) six-hour residue less common than in other gastric lesions; (7) hourglass stomach; (8) patient usually under cancer age and not ill in proportion to x-ray findings. Quoting again from Hartwell's analysis of the 23 authentic cases: "It is worthy of emphasis that these patients all presented much more general clinical picture of carcinoma of the stomach than of ulcer. They were emaciated, their pain was severe, vomiting was marked and gave relief, alkalies did not give relief, and in two of them the radiograph showed conditions which were interpreted as carcinoma. In addition, the HCl content of the gastric juice was low or absent. On the other hand, many of the cases that have been diagnosed syphilis of the stomach on the strength of the Wassermann and the radiograph have proved to be carcinoma."

Although gastric syphilis is apparently a rare condition, the fact that authentic cases have been demonstrated indicates that this organ is not immune to the Spirochæta pallida. Its existence should be kept in mind whenever an obscure lesion of the stomach is found.

**Linitis Plastica.**—In 1864 Brinton described a rare form of gastric disease which was characterized pathologically by a cirrhotic increase of the submucous connective tissue with a sclerotic contraction of the stomach walls causing a marked diminution in the size of the organ. It is known as linitis plastica, leather-bottle stomach, chronic interstitial gastritis, cirrhosis of the stomach, fibroid induration of the stomach, and chronic stenosing gastritis.

*Pathology.*—Two views are held as to its exact classification. According to Leith and others, the pathological picture is one of a benign, atrophic gastritis analogous to a simple cirrhosis of the liver or kidney. Others hold that a carcinomatous infiltration of the stomach wall will give a similar picture and is at least a terminal stage of the so-called benign type. A complete description of the pathology with a report of two cases has been recently made by Andresen. The most comprehensive study of this disease has been conducted by Lyle, who has compiled the records of 114 cases, of which 62 were benign and 52 malignant.

The benign cases may be of two types, the localized and the generalized. Small plaques are found in the former, while in the latter the stomach is hard, fibrous and may be contracted to the capacity of not more than 4 ounces. The duodenum is not involved, but the esophagus may share in the process. Microscopically the connective tissue of the submucosa is hypertrophied and

is associated with an endarteritis which gives the picture from which the term linitis is coined. There may be nests of epithelial cells, possibly isolated from the gastric glands, which simulate carcinomatous tissues.

In the truly malignant cases, the gross effect is the same as the above, but microscopically there is a generalized carcinomatosis.

*Etiology.*—Linitis plastica belongs to the cancer age and is more common in males than in females. Although there are many contributory factors, such as the intemperate use of alcohol and chronic poisoning from other agents, the exact cause of this disease is unknown.

*Symptoms.*—The clinical picture shows nothing characteristic and may easily be mistaken for a carcinoma history.

The onset is gradual, beginning with increasing dyspeptic symptoms such as anorexia, nausea, vague upper abdominal distress, constipation, or diarrhea. Vomiting usually follows and consists of watery mucus although coffee ground material may appear. There is gradual but progressive loss of weight, and in the latter stages ascites may develop.

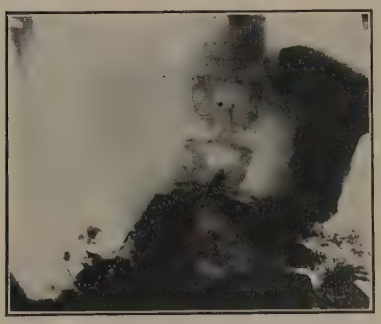

Fig. 25.—Roentgenogram of a Case of Linitis Plastica.

*Diagnosis.*—The chief significant symptom is that due to the small capacity of the stomach (Fig. 25). Food remains in it only a short time before it is passed on or vomited. An Ewald test meal shows a true achylia gastrica. X-ray studies usually reveal a small rigid stomach with no evidence of peristaltic waves. In advanced cases, an elongated mass may sometimes be felt in the epigastrium. It must be differentiated from a movable kidney, malignancy of neighboring organs, or a sacculated tuberculous peritonitis.

**Tuberculosis of the Stomach.**—Tuberculosis of the stomach is a comparatively rare disease occurring in about 2.3 per cent of autopsies on tuberculous cases. It may be primary or secondary, although the great majority of tuberculous gastric ulcers are secondary.

*Etiology.*—The most reasonable explanation for the comparative immunity of the stomach to the tubercle bacilli is based on gastric motility and the absence of lymphatic follicles in the walls of the stomach. The normal gastric mechanism permits of only short exposure to the tubercle bacilli, and unless there is a previous chronic gastric catarrh, the stomach lining is not conducive to a tuberculous implantation.

Secondary gastric tuberculosis may also occur by lymphatic or blood channels. Arloing's investigations tend to make this the most common mode of infection. He was able to produce tuberculous ulcers in the stomach by injecting tubercle bacilli into the blood stream.

*Pathology.*—Bassler summarizes five varieties of tuberculosis of the stomach: (1) The ulcer, sometimes single often multiple, which is rather small with irregular outline, elevated, is somewhat undermined with indurated

margins and rough base, and in which tubercles may be found; (2) miliary tubercles due to the tubercle bacilli entering the blood stream and being disseminated throughout the body; (3) solitary tubercles which are exceedingly rare and probably due to local infection from infected sputum; (4) tumor-like masses usually in the pyloric region which closely resemble a carcinoma; (5) tuberculous cicatricial pyloric stenosis from more or less healed lesions or contractions of perigastric bands due to them.

*Symptoms and Diagnosis.*—The disease is seldom diagnosed before operation or autopsy. It occurs generally during the adolescent period and is slightly more common in males than in females. There are no characteristic symptoms. The ulcer type may simulate an ordinary peptic ulcer although the pain is not severe.

The gastric analysis more frequently suggests a malignancy than an ulcer. Subacidity is the rule and there is often lactic acid, occult blood and gastric retention. X-ray studies are not conclusive, as the pictures may show shadow defects like those of a cancer. Additional light is often thrown on the diagnosis by a study of the patient as a whole. There is usually a slight evening temperature, rapid pulse, loss of weight, and there may be physical signs of a tuberculous involvement in the respiratory tract.

**Foreign Bodies in the Stomach.**—*Etiology.*—Foreign bodies in the stomach are frequent accidents in childhood and are also not uncommonly encountered in hysterical or insane patients. Children may swallow a variety of objects, such as pins, marbles, coins, bones, etc. In the vast majority of instances no annoying symptoms develop, as many of the foreign bodies are passed along the alimentary canal with amazing ease. Pointed articles, as pins and needles, constitute the most serious class. If a pin is swallowed head first, it generally reaches the stomach and after becoming enveloped in food may continue without producing symptoms. If it is passed point first, it may stick on the wall of the esophagus, but even then, food subsequently eaten may force it into the stomach. Open safety pins are notoriously dangerous and very rarely do they pass through the pylorus without producing perforation.

Gastroliths are generally the results of vicious habits on the part of insane or hysterical individuals. Eating bits of hair over a long period of time not infrequently produces hair balls which may sometimes almost entirely fill the stomach. Collections of vegetable detritus may also become impacted firm masses sufficient to cause symptoms (Figs. 26, 27).

Round worms and other forms of intestinal parasites may reach the stomach through the pylorus, and there are records of gall-stones perforating into the duodenum and thence into the stomach.

*Symptoms.*—The symptoms of a foreign body entering the stomach depend upon its size and shape. Small objects such as marbles, coins, etc., often pass through without difficulty and even pins often become encapsulated in the food so that they are passed easily. A needle may perforate the stomach and enter the peritoneal cavity or some adjacent organ without giving rise to any evidences of perforation. Otto reports a patient who swallowed 395

FIG. 26.—PATIENT COMPLAINING OF GASTRIC DISTRESS, AND NAUSEA WITH INABILITY TO VOMIT.

Roentgenogram indicates a freely movable mass in the stomach, producing a defect in the barium meal. In the above illustration the duodenum appears on the right.

needles which gradually appeared in almost all portions of the body at various intervals.

Large objects, remaining in the stomach for some time may set up an inflammatory process and produce an abscess or fistula. In some instances of professional swallowers, however, foreign bodies have been found in the stomach without causing any appreciable lesions. Other individuals may

swallow small objects which may produce a feeling of weight, pain, and nausea. Necrosis may result and occasionally perforations may follow.

*Diagnosis.*—Unless the history is convincing, the diagnosis may be extremely difficult. Metallic or shadow-producing objects can, of course, be demonstrated by a Roentgen-ray examination or by means of a gastroscope. Other objects may be vomited or may ultimately pass through the pylorus and later be expelled per rectum. Not infrequently the diagnosis is not made until an exploratory laparotomy is performed.

**Injuries of the Stomach.**—Injuries of the stomach are relatively common emergency problems. On account of its anatomic relations and clinical manifestations, one is frequently unable to differentiate it from similar injuries to the intestines. The trauma may be due to a sudden overstretching of the organ or it may follow the impact of some blunt or penetrating instrument. The immediate effect of either type of injury is shock. In the first hours after injury it may be impossible to differentiate between perforating and nonperforating injuries of the stomach.

Fig. 27.—Photograph of Mass Shown on Plate in Fig. 26 and Removed at Operation.

It proved to be numerous persimmon seeds firmly imbedded in the stomach. (Reported by W. L. Peple in the *Virginia Medical Monthly*, January, 1922.)

Nonperforating injuries usually are the result of a circumscribed force as a kick or may follow the sudden impact of some blunt instrument. In the minor forms the resulting contusion may be so slight as to produce no hemorrhage, or extensive bleeding may occur in the submucosa, causing a subsequent ulceration. The symptoms of injury to the mucous membranes without perforation are due to the ulcer which follows. In rare instances an abscess may form in the stomach walls or necrosis with secondary perforation may occur. Pain, nausea, and vomiting are generally present and if there has been any tear of the mucous membranes hematemesis will follow.

Perforating injuries of the stomach may result from rupture through pressure or by penetration of some foreign body. Rupture is more likely to occur in the aged. It may be the result of a sudden stretching of the organ with gas or fluid or by unusual pressure against some unyielding part of the body such as the vertebral column or pelvis. As a rule the rupture follows the lesser curvature or attachments of the stomach. If the gastric wall has been weakened by a preëxisting ulcer, perforation is more likely to occur. In several instances rupture has been the result of apparently slight traumatism, especially in cases of alcoholic gastritis. The immediate effect of a traumatic perforation is a contraction of the muscular coat which prevents temporarily

an escape of contents. After several hours relaxation follows with a consequent outpouring of material into the peritoneal cavity.

The symptoms are rather characteristic. They are: (1) well-marked shock; (2) local effect of the perforation; (3) symptoms of peritonitis.

Unless the patient is unconscious the first complaint is intense pain in the epigastrium. Occasionally the symptoms develop slowly and the patient is able to walk or ride some distance before shock develops. The usual picture is a marked pallor, subnormal temperature, clammy skin, pinched expression, feeble rapid pulse, and low blood-pressure. Vomiting of more or less blood generally follows. Unless the patient dies in this stage, there is a temporary improvement before evidences of peritonitis develop. Intense localized pain on pressure and general abdominal rigidity are present. The patient gradually becomes exhausted and death ensues.

**Gastric Ulcer.**—ETIOLOGY.—Although peptic ulcer has been recognized as a clinical entity for practically a hundred years, its actual cause has never been definitely determined. Trauma, psychic influences, irritation from gastric juices and dietary indiscretion have had enthusiastic advocates from time to time, but these hypotheses have never been substantiated by experimental data. More recently the infectious theory has attracted considerable attention and is apparently the most logical explanation of the development of peptic ulcer.

It has been recognized for many years that ulcer symptoms not infrequently develop in conjunction with an acute local process, such as an alveolar abscess, tonsillitis, sinusitis or some other acute infection. According to Rosenow, certain types of organisms, chiefly the streptococcic group, have a selective affinity for different organs in the body and after gaining entrance into the circulation readily reproduce lesions peculiar to that individual strain. He has been able to show that cultures made from an infected tooth in a patient with an ulcer and injected into an animal will frequently create an ulcer in the stomach or duodenum. He has also demonstrated that organisms taken from the crater of the ulcer will tend to produce a similar lesion in the inoculated animal. Although sufficient time has not elapsed for complete confirmation of Rosenow's work, his contributions to this phase of the subject have been the most noteworthy and probably the most important up to the present time.

*Sex.*—Approximately twice as many men suffer from peptic ulcer as women. Although there are no known anatomic reasons for this disproportion, there are apparently other contributory factors: hurried and intemperate eating in lunch rooms, the nervous tension incident to business, more constant exposure, and the frequent excessive use of alcohol and tobacco.

*Age.*—Peptic ulcer is seldom found in childhood and old age. It is most commonly found in the thirties.

*Pathology.*—The simple ulcers vary in size from 1 to 3 or 4 cm. in diameter, some being smaller and others much larger, especially where several have coalesced. They are most often situated on the lesser curvature of the stomach near the pylorus or first part of the duodenum (Fig. 28). Ulcers usually occur singly, although postmortem records show that in more

than 20 per cent of the cases two or more are present. The multiple ulcers are the most likely to be acute.

Peptic ulcers may be superficial involving only the mucosa or submucosa or they may extend through the muscular coat into the peritoneum. Perforation may occur directly into the peritoneal cavity or into one of the adjacent organs such as the gall-bladder, colon, or small intestine.

The relationship of peptic ulcer to carcinoma is still in doubt, although Broders claims that every gastric ulcer is a potential cancer. Certainly ulcers in the stomach are often found undergoing malignant changes (Fig. 29).

Symptoms.—Peptic ulcer may exist for some time without definite symptoms or may occur periodically, being entirely symptom-free between attacks. On account of the various types and localities of lesions, there is no characteristic syndrome by which all ulcers may be recognized. There are, however, certain clinical manifestations which are helpful in arriving at a diagnosis.

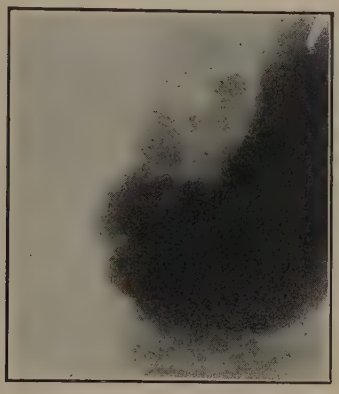

Fig. 28.—Roentgenogram of a Prepyloric Ulcer.

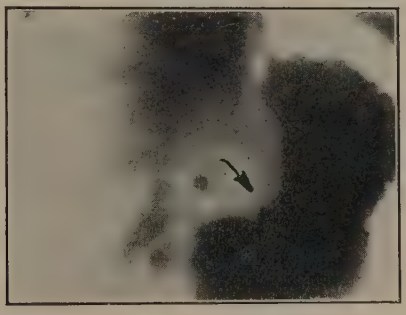

Fig. 29.—Malignant Ulcer on Lesser Curvature of the Stomach.

*Pain.*—Among the symptoms of peptic ulcer pain is the most prominent. It is variously described as boring, sharp, burning, or a constant dull ache. It may be sufficient to require morphin, or it may be only a passing twinge. The pain of an ulcer usually appears from two to four hours after a meal. It is seldom felt immediately after eating or as late as five hours from the time food is taken. The maximum distress is about three hours after the meal. The pain is usually continuous although it may vary in intensity. It is generally felt in the epigastrium either in the midline or about an inch to the right of it. When the ulcer is located in the cardia, the pain is more likely to be referred to the left hypochondrium. In cases of marked gastroptosis the distress may be below the umbilical region. Some authors have attempted to localize the ulcer by the site of the pain, but our experience does not justify any special stress on this point.

The pain is influenced largely by the type of food. Bland articles, such as milk, eggs, cereals, and bread are much less prone to produce distress than heavy and highly seasoned dishes. As a rule the ingestion of foods which

tend to leave the stomach slowly is followed by less pain than the reverse. The administration of alkalies generally brings prompt cessation of the ulcer pain. Accordingly Sippy has recommended a test powder of magnesia and sodium bicarbonate as a differential point from other conditions.

On account of the fact that food often brings relief Moynihan several years ago introduced the term "hunger pain" to designate the sensation described by those suffering from peptic ulcer. Although this symptom is frequently complained of it is by no means pathognomonic of peptic ulcer. In an analysis of 162 gall-bladder and gastro-intestinal infections operated upon at St. Elizabeth's Hospital, the author found that hunger pains were present in 17 per cent of chronic appendicitis, 15 per cent of chronic cholecystitis and in only 50 per cent of peptic ulcer. In the light of this experience, its clinical significance is not as conclusive as is commonly thought.

Hunger pains are in reality intensified normal hunger pangs. Whenever there is a hyperexcitability of the gastric or duodenal mucosa on account of some acute inflammatory process, hyperperistalsis results and the normal sensation of hunger is replaced by an actual feeling of pain. In hyperesthetic individuals hunger pains may arise in the absence of any demonstrable lesion. Hurtz and others have shown that the presence of hydrochloric acid bears no relation to these pains as the latter may occur with an actual deficit of the former. The temporary relief from alkalies, therefore, may not reasonably be attributed to a neutralization of the acid but in all probability to a resulting relaxation of the pylorospasm.

*Vomiting.*—Vomiting is a variable symptom occurring in approximately half of the cases at some time during the course of the disease. It is more likely to occur in nervous individuals as a part of a general hyperexcitability. Starting as a slight nausea it is apt to develop into actual vomiting during the height of the pain, generally bringing temporary relief. When pyloric stricture results, vomiting may become more or less continuous. An unusually large amount of vomitus suggests a pyloric obstruction.

*Hematemesis.*—Care must be exercised in ascribing blood in the vomitus to a gastric or duodenal ulcer. Blood from the teeth, nasopharynx or lungs may be swallowed and later vomited. Gastric hemorrhage may occur from malignancy, cirrhosis of liver, splenic anemia, acute gastritis, varicosed veins, and other causes.

The amount of blood lost varies from a mere trace to a fatal hemorrhage. It may occur suddenly or may ooze for a long period of time, producing a severe grade of anemia. The vomitus has the characteristic coffee-grounds appearance and the stools have a tarry color. Following a hemorrhage the patient breaks into a perspiration; there are extreme pallor, restlessness, and evidences of air hunger. When one large hemorrhage occurs, others are likely to follow, unless treatment is instituted promptly. Small amounts of blood may frequently be found by gastric analysis without any outward evidence of bleeding.

Hematemesis may occur in either sex although it is more common in the male.

*Perforation.*—This is the most serious phase of peptic ulcer and unfortu-

nately is found fairly frequently (Fig. 30). It may be either acute or chronic. In the acute cases, there is a sudden sharp epigastric pain which is usually followed by vomiting. In a short while the pain becomes generalized throughout the upper abdomen and the walls are held with boardlike rigidity. The patient shows evidence of shock and general peritonitis soon develops. In our experience the patient with a perforated ulcer is as a rule remarkably free from a typical ulcer history. The lesion is apparently an acute process and the perforation takes place before the usual symptoms develop. Long standing ulcers may, of course, terminate in a similar manner. In the chronic type, the perforation is incomplete as it becomes walled off by adhesions to adjacent structures. The chief symptoms are epigastric pain, tenderness, a recurring irregular fever, anemia, and gradual loss of strength.

Laboratory Examinations.—*Gastric Analysis.*—Prior to the perfection of the Roentgen-rays, an analysis of the gastric contents was the most important part of the studies on peptic ulcer. Although its practical value has been lessened by the advent of the x-ray films, it still has a definite place in the diagnostic survey and often furnishes information of real value. The majority of ulcer cases have a high gastric acidity, reaching by the fractional method often a reading of 80 to 100 acidity per cent. In some cases, however, there may be no appreciable increase in the acid content and there may be even a subacidity.

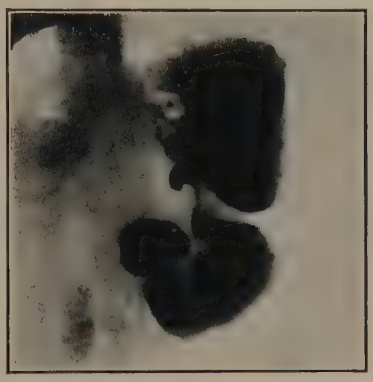

Fig. 30.—Perforating Ulcer of Lesser Curvature with Hourglass Contraction.

The second important part of a stomach analysis is the presence or absence of blood. It must be remembered that blood in the stomach contents may arise from trauma or from the nasopharynx and should not be considered significant, unless these possibilities can be eliminated with a reasonable degree of certainty. The absence of occult blood in the stomach does not exclude a peptic ulcer, although it is generally found in the majority of well-defined ulcers at some time during the history of the disease. Several examinations may be necessary before a positive result is obtained.

There is often a definite gastric retention which can be demonstrated by continuing the fractional determination over the two-hour period. In cases of marked retention, food eaten the previous day as well as sarcinæ or yeast may be found in addition to the usual hyperchlorhydria.

*Examination of Feces.*—Whenever a large hemorrhage has taken place, the stools have a characteristic tarry appearance. In the milder types, there is no gross abnormality of the stools and occult blood may or may not be present. A positive test, however, can be obtained in the majority of ulcer cases where repeated examinations are made. It should be remembered that a meat diet may also give a positive test and that hemorrhoids and other local irritants may cause confusion in the laboratory findings.

*Roentgen-ray Examination.*—In skillful hands, the x-ray examination is the most important single diagnostic test for gastric or duodenal ulcer. As a rule the results are clear cut and when properly interpreted are of inestimable value in the differential diagnosis.

Differential Diagnosis.—There is no single cardinal sign or symptom which may be considered pathognomonic of peptic ulcer. A comparison of preoperative diagnoses with findings at operation has shown that the diseases which are most commonly confused with ulcer are functional neuroses, chronic gastritis, gall-bladder infection, chronic appendicitis, malignancy, and tabes dorsalis. As a rule, the symptoms of gastric and duodenal ulcer are so nearly identical that the distinction is made with diffculty. The most reliable objective differential point is the Roentgen-ray examination to which a reference is made in another chapter.

Gastric neuroses are frequent pitfalls for the diagnostician and are constant sources of apprehension for the operator. As pointed out by Carlston, a hyperesthetic stomach may show hyperperistalsis with typical hunger pain syndrome. When a spastic filling defect is noted in the stomach or duodenum following an opaque meal, the diagnosis becomes increasingly difficult. In such cases it should be remembered that hunger pains may occur in the absence of any organic lesion and are not necessarily indicative of an ulcer. Spastic filling defects will disappear after full doses of belladonna and a further differentiation may be made by a search for other evidence of a neurosis elsewhere in the body. In chronic gastritis, the pain is likely to follow immediately after the meal and is generally a diffused epigastric aching rather than localized in one small area. Vomiting in chronic gastritis is frequent and the stomach contents generally show a subacidity. When doubt exists a barium meal is conclusive.

Gall-bladder diseases constitute the most confusing class to differentiate from peptic ulcer. Here again hunger pains may be found especially where adhesions to the duodenum are present. In our series of cases of chronic cholecystitis hunger pains were complained of in 15.4 per cent. As a rule biliary infections are more frequent in middle-aged women, particularly the obese; the pain is more likely to radiate through the upper right quadrant to the back; there is cutaneous hyperesthesia over this area, and there is generally some tenderness directly over the gall-bladder. Where jaundice occurs, the diagnosis is not so difficult. Gastric analysis usually shows a diminished free hydrochloric acid. The Roentgen-ray findings are generally reliable, but where adhesions to the duodenum are present the picture is not conclusive.

Chronic appendicitis frequently simulates peptic ulcer in its clinical manifestations. Seventeen and five-tenths per cent of chronic appendicitis cases in our series of 162 cases of gall-bladder and gastro-intestinal infections had hunger pains. In this condition there may be a hyperperistalsis with some pylorospasm but no filling defect unless adhesions to the duodenum are present. This possibility may be eliminated by full doses of belladonna before the opaque meal is given.

Another confusing factor in the diagnosis is the frequency with which a peptic ulcer may be associated with a chronic disease of the gall-bladder and appendix. It is not unusual to find the triple infection in the same patient or a history of a previous appendectomy and cholecystectomy in one who now shows evidences of an ulcer. In fact, it is well known that infection in one organ may be carried through lymphatic channels to adjacent sites.

In every case of gastric ulcer the possibility of malignancy as an alternative diagnosis or as a sequel should be kept constantly in mind. The differential diagnosis may be impossible before operation. Although carcinoma usually is found after the so-called ulcer age, exceptions to this rule are too frequent to overlook. There is generally a rapid wasting developing into cachexia which is not characteristic of an ulcer history. The pain in malignancy is more likely to be continuous and lacks the periodicity of hunger pains. Even after the differentiation has been made clinically, there is still the ever present possibility of a cancer developing in the crater of the ulcer. Fortunately a duodenal ulcer very rarely assumes malignant changes.

The gastric crisis of tabes should cause no difficulty in the differential diagnosis provided a thorough physical examination is made. The pain is usually more severe, lancinating in character, and is independent of food. The attacks are more likely to be nocturnal and are often associated with shooting pains in the legs. The blood Wassermann test is positive in only about one half of the tabetic cases, but the absence of one or more sets of reflexes, hypesthesia, etc., are generally sufficient for diagnostic purposes.

Very occasionally the pain of herpes zoster may be mistaken for an acute upper abdominal lesion. The pain tends to radiate in a girdle-like manner and is followed after a few days by a typical vesicular eruption along the distribution of the affected nerves.

**Benign Tumors of the Stomach.**—*Etiology.*—The cause of gastric benign tumor is unknown. There is some reason to believe that mucous polyps are sequels to chronic gastritis, atheroma of the gastric vessels and other chronic nutritional diseases of the mucosa. Benign tumors are relatively infrequent. According to Eusterman's report from the Mayo Clinic, nonmalignant growths constituted only 1.3 per cent of all the 2168 gastric tumors operated upon from 1907 to 1921.

*Pathology.*—The more common benign tumors of the stomach are mucous polypi, myomata, fibromata, myxomata, cysts, and adenomas. Occasionally aneurism may occur.

*Symptoms.*—The symptoms depend largely upon the location of the tumor in the stomach. So long as there is no obstruction to the progress of food, there may be no discomfort. Intramural growths near the cardia are generally symptom-free, but when the pyloric region is involved, acute digestive disturbances usually follow. Pedunculated tumors are prone to prolapse into the pyloric opening, producing symptoms of partial or complete obstruction. Vomiting is frequent and generally contains blood. Loss of weight, anemia, epigastric pain, and other symptoms suggesting a cancer or peptic ulcer are not unusual.

*Diagnosis.*—Gastric analysis offers little definite information. There may or may not be an achylia. Occasionally in cases of mucous polyps, there may be a lack of acid associated with the presence of considerable mucus resembling egg white. In rare instances the finding of a fragment of the tumor in the stomach washings may establish the diagnosis.

The most reliable diagnostic measure is an opaque meal. Basch has enumerated the following roentgenologic characteristics of the pedunculated varieties: "(1) In benign tumors the outlines of the defect are sharp and not ragged or irregular, as in cancer; (2) the greater and lesser curvatures are not implicated in the defect, and there is no break in the peristaltic wave; (3) with change of posture, the plates show a change in size and position of the filling defect, indicating a shifting of the tumor; (4) in cancer of the body of the stomach the shadow is uniformly opaque, whereas in the softer types of hunger polyps, the shadow is translucent."

Generally speaking, when the x-ray findings indicate a large tumor out of proportion to the clinical manifestations, a benign tumor should be considered as a possible diagnosis.

**Malignant Tumors of the Stomach.**—The malignant tumors of the stomach may be divided into carcinomas and sarcomas. About 1 per cent of the gastric tumors are sarcomas which include the myo-, lympho-, and mixed sarcomas. They form solid or cystic growths which begin in the submucosa, or muscularis, finally projecting with or without a pedicle, either into the lumen of the stomach or into the peritoneal cavity. They usually do not damage the mucosa, therefore, ulcerate late and often grow to a very large size. The symptoms and signs are practically those of carcinoma and will not be considered separately.

**Carcinoma of the Stomach.**—*Incidence.*—The stomach is more frequently affected with cancer than any other organ of the body, comprising one-fourth of all cases. It is found in from 1.5 to 4 per cent of all postmortems. According to Welch, cancer of the stomach is the cause of death in 1 per cent of all persons dying after the age of twenty.

Cancer is a disease of late middle life, generally occurring in the sixth and seventh decades. It is exceptional after 70 and very rare before 30. Men are subject to the disease about three times as frequently as women. It is most common in the light-skinned races, the full-blooded negroes being relatively immune.

The cause of cancer is unknown. The only generally accepted causative factor is chronic irritation. It is well known that a malignant growth is prone to develop where repeated trauma exists. The most frequent site in the stomach for mechanical or chemical irritation is the pylorus where cancer most commonly occurs.

The relationship between gastric ulcer and cancer has been seriously studied for many years (Fig. 31). MacCarty has demonstrated certain types of gastric ulcers where cancer cells were apparently growing in the base or its borders. In 1913 Wilson reported the results of the examination of 764 ulcers. Two hundred and seventy-nine showed no cancer, 206 had cancer in the

borders only, and 279 had cancer so distributed that perhaps half had arisen as ulcers and the other half as primary cancer. He concluded that in 60 to 70 per cent of the cases there was some evidence of ulcer formation antedating the cancer.

The New York Life Insurance Company followed up 1761 individuals operated upon at the Mayo Clinic for duodenal ulcers, and 521 with gastro-enterostomies done for gastric ulcer. In the first group the mortality in the first year was 5 per cent which was practically normal for men and women of that age. In the second group it was 17 per cent showing that there is definite danger in leaving gastric ulcers behind. The fact that gastric ulcers sometimes apparently undergo malignant degeneration places them in the category of potential cancers and should be treated accordingly.

In Welch's 1300 cases of gastric carcinoma, the distribution of the growth in the stomach was as follows: pyloric portion, 791; lesser curvature, 148; cardia, 104; posterior wall, 68; the whole or greater part of the stomach, 61; multiple lesions, 45; greater curvature, 34; anterior walls, 30; fundus, 19.

There are four main types of cancer, the adenocarcinoma, the medullary, the scirrhous, and the colloid.

The adenocarcinoma is the most common type and appears as a soft pedunculated tumor projecting into the lumen of the stomach. Its papillomatous projections are strutted with small loops of blood-vessels which bleed easily. On section the tubular structures are lined with cylindrical epithelial cells which are less regular in form and size than those found in the normal glands, and give the characteristics of malignant cells. At intervals they break through the basement membrane and invade the adjacent tissues.

The medullary or soft grandular carcinoma presents fungating masses projecting above the mucous membrane. It is spongy in nature, bleeds readily, and ulcerates early. On section the spheroidal cells seem to grow irregularly and tend to show a predilection for glandular tissue.

The scirrhous type (Fig. 25) is distinguished from the other forms by its hardness which is due to abundance of connective tissue and relatively few cells. It is slow growing, shows little tendency to ulcerate and may have the macroscopic appearance of an old ulcer. Sometimes it is difficult to demonstrate the cancer cells in the primary growth.

The colloid or gelatiniform cancer is simply one of the preceding forms which has undergone a mucoid or colloid change. In character the growth is typical. The very fine stroma with the mass of mucocolloid material gives it a light grayish color. Occasionally the so-called signet-ring cell may be present which is rather characteristic of this type of growth. These tumors are actively progressive and often extend into neighboring organs or infiltrate throughout the gastric walls.

Gastric carcinomas generally stop at the pyloric sphincter and do not involve the duodenum, a fact which has not been satisfactorily explained.

Secondary cancerous growths take place by direct extension, by way of adhesions or by metastasis. The liver is involved in about one-third to one

half of all cases. Metastases in cancer occur by way of the lymph and blood currents, and those in sarcoma practically by the blood vessels only.

*Symptoms.*—Whenever a patient in the cancer age presents himself with a history of persistent gastric distress, malignancy should receive the first consideration. It is not to the credit of physicians to overlook the earliest manifestations of the disease and then recognize it only after the opportunity for relief has passed.

The symptoms of gastric carcinoma depend upon various factors. No disease reveals more clearly the fact that gastro-intestinal symptoms are produced to a large degree by disturbances of the motor functions of the stomach. As long as the organ empties within reasonable time, there may be very minor symptoms regardless of the duration or size of the growth. The relationship of a preëxisting peptic ulcer may give the impression of a slowly developing malignancy as the symptoms of one gradually fade into the clinical picture of the other. In those cases in which there is a history of prolonged symptoms suggesting the presence of peptic ulcer, any change in their customary manifestations after they have reached middle life should be considered suspicious of malignancy. The slow onset occurs in only about one-fourth of the cases.

The more common history is a comparatively sudden development of vague digestive disturbances which may or may not be suggestive. Palliative measures may cause temporary relief but, with the recurrence, general constitutional symptoms such as loss of weight, weakness, anemia, etc., become apparent and the diagnosis of an inoperable growth is then made without difficulty. In cases where the neoplasm has its origin near the pylorus (Fig. 31), an obstruction may be the first symptom and by its severity aid materially in an early recognition of the disease.

Along with the growth of the cancer, more typical late symptoms make their appearance. The *appetite* lessens and there is generally a striking aversion to eating meats. When there is an interference to the passage of food through the stomach, *vomiting* occurs at first intermittently, becoming gradually more or less constant. The vomitus has a coffee-grounds appearance due to the recurring local hemorrhages. Large hemorrhages may supervene, producing a sudden acute anemia. The stools are in the beginning natural in color and consistency but later have the typical tarry appearance. *Pain* may at times be intense. Unlike the pain of ulcer, very little if any relief follows vomiting and food tends to aggravate rather than bring relief.

The general symptoms are fairly typical. *Loss of weight* is in proportion to the activity of the growth and becomes increasingly rapid.

*Cachexia* and *anemia* follow in a short time while *weakness* amounting to prostration is both an early and late symptom.

Toward the close of the disease metastasis to other organs is frequently encountered. The liver, pancreas, peritoneum and lungs are most commonly involved.

*Physical Examination.*—In the early stages of cancer there may be nothing of significance in the physical examination. Any unexplained loss of weight or

anemia in the cancer age should be carefully noted. No masses can be felt in the epigastrium, and it is needless to add that when the tumor becomes palpable it is practically always inoperable.

In the later stages, the patient is thin, undernourished and sallow. The skin is dry and the breath has a peculiar, foul odor. The abdomen may show some distention and often a hard irregular mass may be felt in the epigastrium. In many cases the tumor is palpable only when the patient is in the erect position. Sometimes more satisfactory relaxation of the abdomen may be obtained by having the patient assume the knee-chest posture. The size and contour of the liver should be carefully noted as metastasis to this organ is a common occurrence.

*Laboratory Examination.*—Elaborate studies have been made for some time with the hope that a specific test could be developed which would determine the presence or absence of a cancer in its incipiency. Thus far all investigations have proved futile. Recently Friedenwald and others have found a high sugar tolerance in a majority of gastric cancers, but the value of the test has not been fully demonstrated. The fact that in most cases of cancer of the stomach there is a delayed emptying militates against the accuracy of the test which is dependent upon the absorption of a given amount of sugar from the intestinal tract. Although the laboratory findings are only suggestive at best, they are of value in supporting a suspicious history and should be applied in every case.

Fig. 31.—Prepyloric Filling Defect Due to Cancer.

The gastric analysis often gives information of value. Depending upon the extent to which the cancer has invaded the stomach walls there is usually a relative lowering or even absence of free hydrochloric acid. In some instances, however, a normal acidity may be found. In Hartman's series of 580 cases, 54 per cent showed a lack of hydrochloric acid, 16.5 per cent had a subacidity, 24 per cent were normal and 5.5 per cent were hyperacid. Almost one out of three had normal or hyperacid contents. After the lessening or absence of the acid, there may be a gradual disappearance of the peptic ferments.

Excessive mucus, lactic acid, and Oppler-Boas bacilli make their appearance when definite retention occurs and occult blood is practically always found at some stage during the disease. When a recent hemorrhage has taken place, the blood may appear in the gastric contents in dark red coagulated masses, but old bleeding gives the characteristic coffee-grounds color to the specimens. When minute quantity of blood is present, the benziden or guiac tests may be necessary for recognition. Occult blood in the feces is more commonly found in cancer of the stomach than in ulcer.

The routine blood examinations show nothing of significance other than

a well-marked anemia which in extreme cases may simulate the picture of pernicious anemia.

The roentgenologic examination is generally conclusive in skilled hands and should be made whenever there is any suspicion of gastric malignancy. Carman's classification of the roentgenologic findings is an excellent one and is as follows, in order of their relative importance:

1. Filling defects
2. Alterations of pyloric function
   (*a*) Gaping of the pylorus
   (*b*) Obstruction of the pylorus
3. Perversions of peristalsis
   (*a*) Absence of peristalsis in the involved area
   (*b*) Weak peristalsis
   (*c*) Antiperistalsis
   (*d*) Exaggerated peristalsis
   (*e*) Irregular peristalsis
4. Altered motility
   (*a*) Rapid and irregular emptying (nonobstructive)
   (*b*) Delayed emptying (obstructive)
5. Lessened flexibility
6. Lessened mobility
7. Alteration of size
   (*a*) Shrinking
   (*b*) Dilatation
8. Persistent local spasm
9. Displacement

*Diagnosis.*—The physician never comes in contact with a disease where the early diagnosis is so vitally important as it is in cancer of any part of the body. Generally speaking there are certain so-called constitutional symptoms or signs which are suggestive and when occurring in an individual past 40 should be most carefully considered.

The early diagnosis of cancer of the stomach is exceedingly difficult. There may be no systemic effects and the x-ray examination may not absolutely differentiate it from a gastric ulcer. Persistent digestive disturbances such as epigastric pain, flatulence, regurgitation, and vomiting in an adult who at the same time is losing weight should call for a most rigid examination. The symptoms may be referable to an infected gall-bladder, ulcer, pulmonary tuberculosis, pernicious anemia, or some other serious disease, but in a certain number of cases malignancy will be found as the underlying factor. It is important to consider every persistent general or local disturbance in a middle-aged individual in terms of a possible malignancy until it is proven otherwise. It should be remembered that if the diagnosis is not made until a palpable tumor is found the patient has passed the stage of obtaining a cure.

**Chronic Duodenal Stasis.**—Chronic duodenal stasis is a clinical entity characterized by persistent vomiting, epigastric pain, undernutrition, and constipation.

Crouse recognized the following possible etiological factors: (1) Developmental or acquired adhesions; most commonly those that run from the transverse colon or a displaced hepatic flexure to the underborder of the liver,

Fig. 32.—Dilatation of Duodenum Due to Gall-bladder Adhesions.

gall-bladder, pylorus, or duodenum. These may act either by being directly attached to the duodenum and producing kinks, or by passing across it and by tension compressing the duodenum (Fig. 32). (2) A combination of ptosis of the transverse colon and a short mesentery of the small bowel can cause

the superior mesenteric vessels to compress the duodenum. (3) The duodeno-jejunal angle can also be accentuated by a type of jejunum which drops straight down toward the pelvis instead of running to the left posterior abdomen. (4) Pressure by abnormal conditions of the head of the pancreas. (5) It is not impossible for a sort of atonic ileus to occur due to disturbed innervation of the duodenum or as a constriction formed by spastic circular fibers.

The most common cause is apparently a constriction of the duodenum associated with a visceroptosis. Albrecht has pointed out that the duodenum is normally slightly constricted where it is crossed by the roots of the mesentery and its accompanying vessels. The aorta and vertebral column just posterior to this point form an unyielding surface which acts like one lever of a nut-cracker. Anteriorly the firm mesenteric vessels supply the other lever. It is obvious that any downward drag on the mesentery such as occurs in cases of visceroptosis tends to close the levers. Bloodgood has suggested that in ileal stasis and constipation, the increased weight of the terminal ileum and proximal colon tends to enhance the downward fall. Vander Hoof has also called attention to the fact that in extreme visceroptosis where the intestinal coils rest on the pelvic floor, there is less chance of dragging on the mesentery with its accompanying duodenal compression.

Chronic duodenal stasis is not as uncommon as is generally supposed. Anders writing in 1912 was able to collect 262 cases, and Robinson in 1900 found 15 or 20 incidences in the investigation of several hundred post-mortems. Since this time voluminous reports have been made by Finney, Bloodgood, Ochsner, Mayo and others.

The condition is one of young adult life, occurring more frequently in women. In Vander Hoof's series of 28 cases, the youngest was a girl of 15 years and the oldest was a woman of 62 years. Since the symptoms are essentially chronic, the process may date back over a long period of years.

The symptoms are dependent largely upon the degree of stasis or occlusion. In the mild cases, the clinical manifestations may be rather vague and indefinite. Headache, general weakness, and periodic waves of nausea may be the only complaints. As the condition becomes more marked, epigastric pain is usually complained of. It may be acute and sometimes is referred along the right costal border, simulating gall-bladder disease. Occasionally the pain is of the hunger type variety and is relieved temporarily by food. Most of the patients, however, complain of the pain immediately after eating and associate it with a sense of fullness and bloating.

Although nausea and acid regurgitation occur in the majority of cases actual vomiting is present in only the well-marked types of occlusion. Waves of nausea are frequent, coming without reference to meals. Persistent vomiting may result in acidosis and death of the patient. In some instances, however, vomiting may continue over a considerable period of time without giving rise to serious complications. Many cases of supposed hysterical vomiting, which were probably due to this condition, have been relieved by rest cures.

Patients with chronic duodenal obstruction are always below weight for

their height. Many of them are thin-chested, with long waists and show the typical habitus enteroptoticus.

The *diagnosis* is suggested by the history and evidences of a visceroptosis, but confirmation of these findings is dependent upon a careful x-ray examination. In skillful hands the fluoroscopic picture is conclusive and where the history warrants such a procedure x-ray films should be made. It should be remembered, however, that the condition may be periodic and if the examination is made when the patient is free from symptoms, no abnormality may be observed.

**Tumors of the Duodenum.**—Tumors of the duodenum may be either benign or malignant. Benign tumors are very uncommon. They include adenomas, polyps, lipomas, myomas, fibromas, myxomas, angiomas, and other extremely rare neoplasms.

The *symptoms* are largely mechanical, producing evidences of partial or complete duodenal obstruction. Depending upon the location and size, such tumors may cause jaundice and other manifestations of biliary disturbance, or signs or symptoms of an actual intestinal occlusion may develop.

Malignant tumors may be either sarcoma or carcinoma. Sarcoma is exceedingly rare and clinically offers no features which differentiate it from a carcinoma.

Carcinoma of the duodenum appears in about 4 per cent of intestinal carcinomas (Geiser). It is relatively rare, Carman having reported only 5 cases at the Mayo Clinic, prior to 1922. According to Ewing, three distinct forms may be recognized: (1) carcinoma following ulcer; (2) carcinoma at the ampulla of Vater; and (3) carcinoma of the distal portion of the duodenum.

In Rolleston's series of 40 cases, 8 were in the first portion, 24 in the second, and 3 in the third portion. Following the development of a duodenal carcinoma, stenosis and adhesions are present. Metastases are frequent and widespread. Jaundice is an early and constant symptom where the neoplasm develops near the ampulla of Vater.

Carcinoma of the distal portion is rare, but when it does occur the symptoms are those of a rapidly developing obstruction. Jaundice is usually absent, but nausea and vomiting are persistent.

**Duodenitis.**—*Etiology.*—Duodenitis is usually an extension of an inflammatory process from the stomach. It may be a part of a general systemic disease or it may be the result of pathogenic organisms passing through the pylorus and invading the duodenal mucosa. There is some reason to believe that infection from the tonsils, sinuses, and teeth may cause duodenitis by the hemotogenous route. Infections may also arise through dietetic errors such as eating spoiled foods, unripe fruit, etc., the result of which may be a part of an acute gostro-enteritis.

The bacteriology of the duodenum was never thoroughly worked out until the recent studies of Lyons in connection with duodenal drainage. He has reported the frequent finding of various strains of streptococci, staphylococci, colon and typhoid bacilli, and occasionally diphtheria bacilli. The gall-bladder

may harbor one or more of these organisms which are expelled intermittently into the duodenum.

Duodenitis may be acute or chronic. Acute catarrhal duodenitis frequently exists unrecognized, especially if it is a complication of some other acute infection like typhoid fever. There may be a heavily coated tongue, anorexia, and extreme gastric irritability. In some cases pain and tenderness in the region of the gall-bladder may be present. When the inflammatory process involves the ampulla of Vater, jaundice usually develops and becomes the most conspicuous and stubborn symptom. The stools are clay-colored and bile appears in the urine. The duodenal contents show many cuboidal epithelial cells, bile-stained mucus, and bacteria. The process usually terminates in recovery.

Chronic catarrhal duodenitis is recognized with great difficulty. It may follow one or more attacks of acute duodenitis. As a rule there is an associated involvement of the bile ducts, and in some cases chronic cholecystitis, cholangitis, and pancreatitis follow extension of the process.

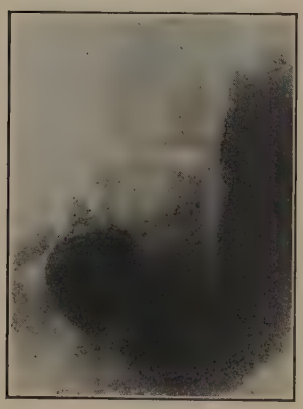

Fig. 33.—Duodenal Ulcer with Gall-bladder Adhesions.

The *symptoms* are characteristically vague. The appetite is apt to be poor, there is considerable eructation, some regurgitation, periods of nausea are common, and there may be typical hunger pains coming about two or three hours after eating. The complexion may be sallow or actually icteroid, depending upon the degree of obstruction at the ampulla of Vater.

The gastric analysis as a rule gives little information as there may be any variation in the acid content. The duodenal contents show an abnormal amount of leukocytes and epithelial cells. There are usually microörganisms and mucus in abundance. There is nothing characteristic in the x-ray findings.

**Duodenal Ulcer.**—Duodenal ulcer has certain distinctive features which should be emphasized. It is more frequently found in men than in women. This may be due to the anatomic difference between the position of the duodenum in the male and that of the female. In the former the duodenum ascends sharply in its first portion and its second descends to the common bile duct, whereas in the female the first portion lies more transverse, thereby allowing the bile and pancreatic juices bathe the first portion of the duodenum with an alkalinizing fluid.

Duodenal ulcer is more constantly associated with a high gastric acidity than is ulcer of the stomach, and is less frequently attended by hematemesis than is gastric ulcer. Vomiting is noted less than in gastric ulcer. Malignancy rarely develops in a duodenal ulcer, which is in striking contrast to its frequent association with a gastric ulcer (Fig. 33).

The etiology of duodenal ulcer is the same as of gastric ulcer. There is, however, a peculiar type of duodenal ulcer which develops after extensive

cutaneous burns. No definite explanation is forthcoming other than the proposal of some toxic substance which is secreted in the bile after burns, thus injuring the mucosa. These ulcerations are often multiple and occur in 6 per cent of fatal burn cases.

The symptoms and clinical findings of duodenal ulcer in other respects so easily simulate those of gastric ulcer that a repetition of them is not considered feasible. The reader is referred to the section on diseases of the stomach for a further discussion of this subject.

**Diverticula of the Duodenum.**—Diverticulum of the duodenum is the result of a congenital or acquired structural defect in the duodenal wall, occurring most frequently at the site of Vater's ampulla. Those instances where the diverticulum has been found near the pylorus are generally associated with ulcer and according to Holsweissig are the result of traction in cicatricial tissue. It may become chronically infected, giving rise to symptoms similar to that of the ordinary chronic ulcer.

In a review of about 2200 stomach cases in which Roentgen-ray examinations had been made, Andrews found that more than 300, or 14 per cent, showed deformity of the duodenal canal, of which 26, or 1.2 per cent, resembled diverticula.

In Case's series, diverticula were found in 85 out of 6847 cases or 1.2 per cent. The average size of the sacculation was 2.8 cm. The average age of the patient was 56 years. In 18 cases of this group the average emptying time of the sac was 11 hours while the normal emptying time of the duodenum is 4 or 5 hours. The diverticulum may be covered only by the mucous layer and, as shown by Case, the muscularis was lacking over most of the sac in every instance.

The diagnosis rests almost entirely upon roentgenologic findings but the results are not uniformly satisfactory. Differentiation must be made between an ulcer pocket, ulcer diverticulum, barium filled gall-bladder after cholecystostomy, and visible gall-stones.

The symptoms are rather vague and are of little assistance in the recognition of this condition. There may be some epigastric discomfort or acute pain. Eating as a rule aggravates the symptoms, while lying in a prone position tends to afford some relief.

## POSTOPERATIVE DIETARY TREATMENT OF GASTRIC SURGICAL CASES

The surgeon's obligation to his patient is not discharged solely by operative treatment. Unless proper attention has been paid to the preoperative as well as to the postoperative periods, the chances for a satisfactory result are immeasurably lessened.

There are certain general considerations which should be emphasized in the dietotherapy of gastric surgery. The selection of the type of food deserves the first attention. Custom and unsubstantiated ideas have encouraged the

use of certain foods in postoperative cases which should be severely condemned. An ideal diet for surgical patients of this kind is one which gives as nearly as possible physiological rest to the stomach, lessens gastric secretion, leaves little residue, is not gas-forming, and supplies an adequate amount of calories for the bodily needs.

Sweet milk should not be used on account of its gas-producing qualities and tendency to encourage constipation. Meat broths are notorious stimulants of the gastric juices and, of course, are not advisable in any form. Raw eggs given alone or in the form of albumins have been in vogue for many years and in spite of numerous experiments to the contrary are still recommended in some modern textbooks on diets. Briefly, Bateman and others have shown that (1) egg white has a strong antitryptic action; (2) as high as 50 per cent is lost in the feces; (3) it tends to produce gastro-intestinal upsets; and (4) at times it apparently causes an albuminuria, a condition certainly not to be desired in postoperative cases where the kidneys are already overworked.

The importance of a liberal fluid intake before operation cannot be overemphasized. The fact that postoperative shock has been shown to be due probably to a lowered blood volume resulting from a capillary leakage is a stern rebuke to the former custom of unconsciously producing actual preliminary dehydration by withholding fluids previous to operation. Water should be given in abundance and food rich in carbohydrates should be advised as a preoperative measure.

The postoperative management is more complicated because the problem is one involving not only an organ temporarily *hors de combat,* but also a systemic disturbance of more or less gravity. In selecting the diet due consideration must be made for each case, as the type of operation, complications, and quality of existing physical impairments and idiosyncracies in the patient will determine to a large measure the most acceptable form of nourishment. We have at St. Elizabeth's Hospital a series of six diets, varying from fruit juices to regular meals which form the basis of treatment, subject, of course, to the above-mentioned factors.

Following the operation, the patient usually receives no food by mouth during the first 24 or 48 hours. Water and crushed ice in small amounts are, as a rule, given in this interval, provided nausea and gastric retention do not interfere. In many instances gastric lavage shortens this period of discomfort and permits the freer use of water or crushed ice. By the second or third day, fruit juices with lactose are usually acceptable and are well borne in uncomplicated cases. It is important to emphasize the futility and actual harm of forcing water or fruit juices by mouth during this period if the lavage shows a definite retention.

The amount and character of food after the second day are largely dependent upon the nature of the operation. A posterior gastro-enterostomy, as a rule, causes the least early disturbance of the major operations on the stomach, but its late effects are generally more prolonged. Such patients can usually retain fruit juices in small amounts on the second day and by the

third or fourth day are able to take as much as 1500 calories in the form of oatmeal gruel, buttermilk, cocoa with lactose, cream, etc. Not over three ounces are given every two hours and lavage is resorted to if there is any appreciable gastric retention. Soft-boiled eggs, baked custard, creamed soups, farina, etc., are gradually added so that in the majority of cases a sustaining semisolid diet is being given by the eighth day. When the patient is discharged from the hospital he should be advised as to the nature of the operation and the importance of continuing a special diet for six months. He should be provided with a list of allowable foods which should not include heavy meats, coarse vegetables, fried foods, acids, carbonated water or alcohol. During this period intermediate nourishment in the form of milk or crackers should be taken.

Owing to the nature of the operation, the régime following a pyloroplasty cannot be carried out so rapidly. The fact that the pylorus has been temporarily traumatized tends to interfere with the immediate emptying of the stomach and, therefore, calls for a more restricted dietary outline. Early lavage is more frequently done on patients undergoing this type of operation until the function of the pylorus is restored. The inhibition, however, usually manifests itself only during the first two or three days, after which time the dietary measures as suggested above are followed.

After operations for cancer of the stomach, the diet will depend upon the extent of the surgical procedure. When a part of the stomach is removed, the chief consideration from a dietary point of view is a reduction in the amount of food at each feeding. Gastric retention and associated disturbances are frequently encountered in this condition and may prove a serious handicap to the patient's recovery. It is advisable to restrict the nourishment to feedings of one to three ounces until the immediate effect of the operation has passed.

(All roentgenograms reproduced in this chapter, not otherwise credited, are used through the courtesy of Dr. Fred M. Hodges.)

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# CHAPTER V

## GENERAL CONSIDERATIONS

**The Operating Room.**—The operating room for surgery of the stomach and intestines requires nothing particularly unusual. There should be a good light, and the regular equipment for doing clean surgery. Not infrequently surgery of the intestines and stomach may prove to be emergency work, and it is essential to have artificial lighting that will be sufficient to show the tissues well, that will cast as little shadow as possible, and that will be adjustable. The chandelier which often hangs over the operating table is undoubtedly a potential source of infection. It is difficult to clean and even with the most conscientious care may be a harboring place for dust. Lighting fixtures are doubtless used in not more than 5 per cent of the operations, and they are not only useless in the daytime but a real menace to aseptic surgery.

Probably the most satisfactory lighting fixture is a small crane which can be swung back or folded against the wall during the daytime. In this way there is nothing hanging over the abdominal incision during the day, and consequently a source of contamination from dust is eliminated. Then, too, the crane can be readily made adjustable. The electric bulb is placed on the end of a rod with a telescopic effect that can be lengthened or shortened and raised or lowered by making a slight mechanical adjustment at a joint at the end of the crane. If desired a shade consisting of a sterile towel is fastened by a hemostat over the upper part of the light before it is placed in position. A single large nitrogen-filled electric bulb gives sufficient light which is fairly white. Bulbs may be colored a slight bluish tint if desired, but this is usually not necessary.

Some equipment houses now make a portable stand for light, which is excellent and also removes the menace of a fixed chandelier constantly hanging over the wound.

Air infection was at first overemphasized, then neglected. Undoubtedly many infections that cannot be otherwise accounted for come from the air. If there is a passageway from a room above the operating room or from a room near the kitchen on the top floor, there may be a current of dust-laden air. Sterile petri dishes with the proper culture medium placed on the operating table, sealed at the end of operation and incubated will give an accurate idea as to the possibility of air contamination. It is best to have the operating room on the top floor, as far as possible out of the dust line. Fireproof construction, of course, adds greatly to the lessening of dust.

The construction of some operating rooms is such that the sterilizing apparatus is either in the operating room or immediately adjacent to it. This is unfortunate, because occasionally in abdominal operations for peritonitis a

drop or two of the septic exudate may become dried, inspissated, and will then float in the dust and lodge on some of the dressings or contaminate the instruments after they have been removed from the sterilizer. Then, too, ether vapor is highly inflammable, and ethylene, which is used at many clinics, is even more so. If the sterilization is done with an open flame it would be unsafe to use ethylene in an operating room in which there is an open flame, or even when the sterilizing room opens directly into the operating room.

A possibility of infection from coughing or from talking, particularly during an epidemic of colds, should be guarded against. Mouth masks should contain a number of layers of gauze or some soft cloth. The gowns of visitors who stand about the table should be preferably sterile and the visitors, as well as the operating assistants and nurses, should wear masks.

No unnecessarily complicated instruments should be used. Self-retaining retractors may give excellent exposure, but at the price of considerable injury to the abdominal wall which may lead to infection. It must be remembered that strong retraction produces anemia in the tissues under pressure. When a self-retaining retractor is used it would be well to relax the pressure upon the tissues occasionally by loosening the retractor and so permitting at least an intermittent blood supply to the margins of the incision that are retracted.

**Anesthesia.**—The question of anesthesia has to be determined in the individual case. If the patient's general condition is good without any affection of the heart, lungs, or kidneys, ether is usually a satisfactory anesthetic when properly given.

Chloroform may occasionally be indicated in a short anesthesia, but is always dangerous. Its administration requires considerable skill and it should never be used in prolonged anesthesias. It has the disadvantage of having a depressing effect on the heart, which may come on suddenly, and its late effects upon the kidneys and liver are often deleterious. Sometimes after a prolonged administration of chloroform fatty degeneration of the liver occurs.

Nitrous oxid gas with oxygen is used as a general anesthetic, but without combination with ether or without a local anesthetic, frequently does not produce sufficient relaxation for abdominal operations. Nitrous oxid with oxygen is dangerous in prolonged anesthesias, on account of its action on the heart, but is a popular induction anesthesia for ether.

Ethylene is one of the most satisfactory general anesthetics, and has many advantages over ether or nitrous oxid-oxygen. It is our routine anesthetic. It is given in combination with oxygen, and apparently has no irritating effect upon the trachea or bronchi, nor upon the kidneys. It is followed by less nausea and vomiting than ether produces. Ethylene seems to stimulate the heart. It was introduced as a general anesthetic by Arno B. Luckhardt, professor of physiology at the University of Chicago, whose work with his colleague, Carter, demonstrated experimentally that ethylene given to animals to the extreme extent would cause death by cessation of respiration some time before the heart stops. In Luckhardt's experiments animals that had been fully anesthetized with ethylene for several hours would, as one of the early signs of danger, cease breathing. If the animal was taken from under the influence

of ethylene and given artificial respiration, breathing would be resumed. In all of this time the heart beat would continue. This is a very marked advantage. Dr. W. H. Higgins, the head of the Medical Department of St. Elizabeth's Hospital, thinks that ethylene is a distinct stimulant to the heart even in cases of chronic myocarditis. It is well known that nitrous oxid-oxygen anesthesia, while comparatively safe for short operations, is increasingly dangerous with the length of operation. In prolonged operations under nitrous oxid-oxygen sudden death may occur, and frequently the first sign is cessation of the heart beat. These deaths sometimes come on with alarming suddenness, and the usual efforts at resuscitation are frequently futile. Ethylene with oxygen does not produce such marked relaxation as ether, but the relaxation seems to be somewhat greater than with nitrous oxid-oxygen. When greater relaxation is necessary ether can be used in addition to ethylene. Arrangements for this are made in most of the better types of apparatus used for the administration of an anesthetic gas, so that ether can be switched on at once after the patient has been anesthetized with ethylene. With experienced anesthetists, however, the use of ether becomes less and less frequent, and in the majority of our abdominal operation, even in the upper abdomen, straight ethylene and oxygen anesthesia is all that is necessary. The administration of carbon dioxid up to 5 per cent dilution often gives better relaxation and abolishes to a large extent the breath-holding reflex in the early stages of ethylene anesthesia.

One of the chief disadvantages of ethylene is its inflammability. It has been shown, however, that it is no more inflammable than ether vapor, though because it is lighter and more diffusible there is a greater tendency to explosion. This can be safely prevented by not giving ethylene in a room with an open flame, by avoiding the use of a cautery near the head or chest and providing a current of air to blow the ethylene away from the cautery wherever it is used, by establishing sufficient ventilation, and by always grounding the anesthetic apparatus with copper wire hooked to a pipe or a radiator. All of these precautions are important, but with them there should be no danger from ignition or explosion.

Local anesthesia may be employed either in connection with nitrous oxid or ethylene, or independently. It undoubtedly has a very decided field in abdominal surgery. The work of Farr, Finsterer, and others has shown to what extent very radical abdominal operations can be done under local anesthesia. In many cases, however, as when the patient is very fat or nervous, a general anesthetic is better. In radical operations on the stomach, particularly for cancer, local anesthesia is often safer than any general anesthesia, even ethylene, which seems to be the least injurious of the general anesthetics. In patients with cancer of the stomach there is nearly always some degree of malnutrition, and every possible effort should be made to conserve the vital forces. By infiltrating the abdominal wall not only in the line of incision but for several inches on each side of the proposed incision with a solution of one half of one per cent of procain containing one or two drops of 1:1000 adrenalin solution to the ounce of procain solution, a

very satisfactory anesthesia is obtained. It must be recalled that the parietal peritoneum in itself is probably not sensitive, but its supporting tissue carries a fairly rich sensory nerve supply. This tissue should be well infiltrated on each side of the incision. After opening the abdominal cavity, the retroperitoneal tissues about the solar plexus and the retroperitoneal tissues just above the lesser curvature of the stomach should be infiltrated. The tissues around the pancreas and the gastrocolic omentum are also injected. Care should be taken to avoid injecting blood-vessels, particularly the vena cava or the abdominal aorta. With reasonable care, however, such accidents are avoided. Resection of most of the stomach can be done by such measures with great satisfaction. In two cases within the last few months I have been able to resect about half of the stomach under local anesthesia and the patients left the operating table with a pulse of not more than 80—a procedure that would be unusual with any general anesthetic. In such operations as gastro-enterostomy or pyloroplasty, with the patient in good general condition, a general anesthetic may be safely used, but when there is pyloric obstruction or the patient's condition is bad gastro-enterostomy can be readily done with a local anesthetic. In hemorrhage from the stomach, especially postoperative hemorrhage after a gastro-enterostomy, the wound may be opened under local anesthesia and an incision made in the anterior wall of the stomach and the site of the gastro-enterostomy pushed into the gastric incision with one hand below the transverse colon.

**Frozen Sections.**—The operating room should be in close proximity to a laboratory, for occasionally frozen sections may be required during the operation. Usually when the surgeon has had some training in pathology the gross appearance of the tissues will indicate whether there is malignancy, but occasionally such a decision cannot be made without the aid of the microscope, and here an immediate fresh frozen section is a great help. It should be interpreted, however, by one who is sufficiently trained in pathology, either by the surgeon himself, or else by a tissue pathologist, because the pathologic report may do more harm than good if it is not made by some one who is competent.

Bacteriological examinations are not infrequently helpful. When a localized abscess or suspicious fluid is encountered, bacteriological examination with a smear and immediate report may determine whether drainage should be employed or whether the operation should be continued, regarding this fluid as practically sterile. Drainage should never be used indiscriminately, and should be particularly avoided whenever any suturing of the stomach or intestine is done.

**Shock and Hemorrhage.**—In hemorrhage following operations upon the stomach and intestines blood usually appears in the gastro-intestinal tract and is often vomited. Occasionally, however, there may be considerable bleeding before there is any vomiting. If the hemorrhage is in the small intestine the blood often is only in the stool. This is a common symptom in typhoid, but also occurs in other ulcerated conditions of the small bowel, and particularly in ulcers of the duodenum.

Shock and hemorrhage frequently go hand in hand. A patient who has lost even a moderate amount of blood is much more likely to enter a state of shock than if no blood had been lost. Shock may occur without loss of blood after long operations in which there has been considerable manipulation. Every effort should be made to prevent shock and hemorrhage. Hemorrhage can usually be prevented by care in the dissection and by clamping and tying bleeding points. Occasionally if there is much inflammation and marked oozing, packing will be necessary to control hemorrhage.

Cannon's view of traumatic shock, that it is due to some toxic product elaborated by the injured tissues, must be borne in mind. Some tissues make such a toxic product more readily than others. Unusual and unphysiologic conditions often predispose toward shock. Thus the exposure and drying of the peritoneal covered bowel, massage or pressure upon any considerable segment of the stomach or bowel may produce some of the histamin-like toxic products that cause shock. Cannon's work seems to have shown quite clearly the etiology of traumatic shock and the necessity of reducing injury to tissues and exposure of the peritoneum to the minimum. The insistance for years of Crile upon gentle handling of tissues in every portion of the body is a doctrine that should be borne in mind, particularly in abdominal surgery. The use of an unnecessary amount of gauze for packs causes additional trauma. Not infrequently the water in which these packs are soaked is too hot. It is better to put in dry gauze or gauze soaked in cold salt solution than to use salt solution that is too hot. The delicate endothelium may be greatly injured by the excessive heat. The use of a cautery is also a great predisposing factor to shock. While the electric cautery is a valuable instrument in dealing with malignant tumors of the stomach and intestine, a dissection with the cautery destroys more tissue and makes more of the shock-producing toxins than a dissection with the knife. The use of the cautery in merely dividing the bowel or stomach, particularly when the bowel or stomach is clamped and the absorption from the cauterized area is temporarily blocked is, of course, justifiable, but whenever the cautery is employed extensively either in the abdominal cavity or elsewhere, symptoms of shock must be carefully watched for and combated as soon as possible.

The loss of body fluids also predisposes to shock. When hemorrhage occurs a moderately low blood-pressure tends to promote clotting. But if the blood-pressure is so low as to affect the cerebral centers, the patient may enter into a dangerous state of malnutrition of the centers of the brain. If the hemorrhage can be readily controlled there is no objection to raising the blood-pressure, but the patient should not be overstimulated. In shock in which there has been no hemorrhage, or when the hemorrhage has been controlled, the danger of recurrent bleeding does not exist. In any case when in doubt fluids should be supplied quickly, and when shock is anticipated it is well to have hypodermoclysis of Locke's solution or of 5 per cent glucose in Ringer's solution given on the table. This can be administered through a long needle which goes from a point just external to the mammary gland up toward the axilla. The point of the needle should rest in the loose areolar

tissues along the base of the axilla, and not under the mammary gland as was formerly taught. The solution should not be permitted to flow too rapidly, though a moderate amount of tension is necessary to promote absorption. After a few hundred cubic centimeters are given if the absorption is not rapid the needle may be transferred to the other side, or in a case in which the need seems to be rather urgent the hypodermoclysis may be given on both sides at the same time. If this does not avail and the patient's blood-pressure is going down, more radical measures should be adopted. Blood-pressure as an indication of shock depends of course upon several things, mainly upon its relation to the normal systolic and diastolic pressure of the patient. A patient who has a high systolic blood-pressure will stand very poorly a drop of systolic pressure to 100, whereas a patient with a systolic pressure of 120 may not be seriously affected by a drop of 30 points, provided it is not too rapid.

The diagnosis of hemorrhage is, of course, obvious when blood is vomited. Hemorrhage from the gastro-intestinal tract is rarely into the peritoneal cavity. If it occurs as a result of a perforation of an ulcer, which is very unusual, the symptoms that first attract attention are those of a perforated stomach or bowel. They are violent pain, muscle spasm, and shock, later followed by elevation of temperature as the peritonitis begins. Differentiation between shock and hemorrhage when the bleeding is not visible is sometimes confusing. The prime symptoms in both of these conditions are due to lack of satisfactory blood circulation to the vital cerebral centers and this may be brought about either by bleeding from the vessels or by the loss of fluids of the blood into the dilated capillaries and the tissue spaces. If the bleeding comes from the stomach, the stomach should be thoroughly washed out with hot water until the clots have been removed. A weak soda and salt solution at a temperature of about 120° F. is a satisfactory solution for the gastric lavage. Emptying the stomach causes its muscular wall to contract as emptying the uterus, and so may stop the bleeding. The hot water tends to cause contraction of the stomach, and apparently contraction of the blood-vessels.

Shock and hemorrhage often occur together but in shock without bleeding there is marked concentration of the blood due to the fact that the fluid elements leave the vascular system and, even though the patient may be desperately pale, the blood will often show high hemoglobin and a high red-cell count as well as an abnormally high white-cell count. In hemorrhage somewhat the same phenomenon may appear at first, but it is not so marked. After the blood has become diluted by absorption of Locke's solution or salt solution the hemoglobin and red cells fall. In pure shock when the hemoglobin and red cells begin to fall it is usually a favorable sign because it shows that fluids are being retained in the vascular system.

Transfusion of blood may be said to be a specific for hemorrhage or shock if used before the condition is too desperate. If the cerebral centers have become profoundly affected by the anemia, either from bleeding or from the accumulation of the vascular fluid in the tissue as in shock, permanent cerebral changes may have taken place and even restoration of the normal pressure

may not save the patient. In cases that have not been too long neglected, however, a transfusion of blood is followed by a surprisingly rapid recovery.

If a donor for transfusion is not available, intravenous injection of 0.9 per cent salt solution will raise the blood-pressure, but this is very evanescent. An artificial colloidal solution is too often followed by late affection of the kidneys or other complications to render the routine employment of such a measure safe. Matas uses the slow injection of 5 per cent glucose into a vein. This may be regulated according to his method by a type of drip somewhat like the Murphy drip, so that only about 100 c.c. an hour are instilled into the vein. In urgent cases, of course, it should flow more rapidly. We use a long cylindrical container, somewhat like a burette, and while the flow cannot be as accurately measured as after the drip method, it can be made to go sufficiently slowly and does not require the same careful watching as the drip method. This method of Matas is exceedingly valuable. The glucose not only acts somewhat like a colloid in retaining the blood-pressure by remaining in the vascular system, but it furnishes very valuable nutrition to the heart and to the tissues generally. When a donor is not immediately available the blood-pressure should not be permitted to fall too low and during the preparation for matching the blood for subsequent transfusion a 5 per cent glucose solution can be used intravenously, which will keep up the blood-pressure at least until the transfusion of blood can be done. It is important not to let the systolic pressure get below 70 in any case, and in patients with a normally high blood-pressure the minimum systolic pressure should of course be higher. The 5 per cent glucose can be prepared by ordinary sterilization just as salt solution is prepared. It does not require the elaborate technic of filtration as was formerly thought. The glucose should, however, be pure and the water should be freshly distilled. After the blood-pressure has been raised to a satisfactory level by the injection of several hundred c.c. of 5 per cent glucose, a small amount, say from 50 to 100 c.c., is given hourly until the symptoms have been greatly improved. According to Matas, this may be continued for several days. We now use 5 or 10 per cent glucose usually in Ringer's solution made from freshly distilled water. After four or five thousand c.c. are injected, the straight glucose solution in freshly distilled water is employed. About 15 or 20 units of insulin are given after every thousand c.c. of the glucose solution.

**Transfusion of Blood.**—The technic of transfusion of blood is described in works on operative surgery. When the blood is carefully matched and the transfusion quickly made the indirect methods, such as the Percy or the Kimpton-Brown methods, are usually satisfactory. The citrate method can also be used, mixing the blood with 0.2 per cent citrate of soda solution. There is, however, very much more likelihood of reaction after the indirect method, and particularly after the citrate method, than after the direct method of transfusion. With great care some operators have been able to cut down the reactions after the indirect method, and particularly after the citrate method, to a small percentage, but this requires extreme accuracy in matching the blood, which should be observed for several hours, and the donor's blood

should be matched directly against the patient's blood. It must be borne in mind that when transfusion of blood is necessary in surgical cases the patient is usually very ill, and a marked reaction may be deleterious and may, in fact, do as much harm as the transfusion does good. Personally I have been using for the last four years the method of transfusion with the Bernheim cannula in which the radial artery of the donor is united by the cannula to one of the patient's superficial veins on the forearm or elbow. The fresh oxygenated arterial blood of the donor is thus pumped directly into the veins of the patient. A careful observation of both donor and patient is made at intervals of two minutes, including pulse rate and blood-pressure. If the donor has a large radial artery and good pressure, ten minutes of flow is usually sufficient, though it may be continued longer. If the cannula clots it can be unjointed and the clot cleaned out with a silver probe. If the clotting occurs again it is best to insert another cannula.

The chief argument against direct transfusion is that the quantity of blood transferred cannot be measured accurately. All drugs and therapeutic remedies are given to accomplish a desired result, and not for the sake of administering a certain measured amount. The measured dose is merely a matter of convenience. In giving ether for anesthesia, for instance, the anesthetist does not purpose to use a definite measured amount of ether, but administers enough to accomplish certain therapeutic effects, whether it take 2 ounces or 16 ounces for the anesthetic state. The same is true of other drugs. And so blood is given by transfusion until the patient shows by pulse rate, blood-pressure and other symptoms that he is sufficiently benefited, or until the donor shows distress. This condition can be obtained more accurately by observing the patient and the donor at intervals of two minutes, as has been suggested, than by merely giving a stated amount of blood.

In indirect transfusion there is no opportunity for identifying changes that may occur when the blood is stagnant outside of the vascular system, even for a fraction of a minute. We know that clotting takes three or four minutes, yet the process of clotting has never been accurately explained from a chemical standpoint except by an hypothesis that assumes certain thromboplastic substances to be present or the release of such substances as prothrombin after antithrombin has been satisfied (Howell). It must be assumed, however, that these changes do not occur instantaneously at the end of three or four minutes, but that chemical changes altering the constitution of the blood begin soon after the blood leaves the vascular system. These changes are not very marked, but it seems reasonable to believe that blood directly pumped from the arterial system of the donor to the venous system of the patient with the mere interposition of a silver tube about 3 inches (7.7 cm.) in length, is in a more nearly physiologic condition than when it is drawn into a receptacle and permitted to stand even for a period of a half minute. With one who is accustomed to transfusion and a careful matching of blood the indirect methods of transfusion usually give satisfactory results, even though followed by more reactions than occur after the direct method. The chief objection to the direct method is that it requires a short incision

over the radial artery of the donor. For the Bernheim cannula this incision need not be more than an inch in length. Professional donors, however, often object to even such a short incision, though donors who are relatives or friends do not mind it. When blood is quickly transferred from the vein of the donor to the vein of the patient, as exemplied by the Lindemann method, it is out of contact with the vascular system for such a short time that it approximates the advantages of the direct method.

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## CHAPTER VI

## SUTURING THE STOMACH AND SMALL INTESTINE

As far back as 1396, Lanfrank, in his *Science of Cirurgie,* described a method of closing intestinal wounds by suturing the parietal peritoneum to the visceral peritoneum. More than 400 years later Benjamin Travers, after experiments on dogs, showed that it was not necessary for the intestinal wound to be fastened to the parietal peritoneum, but that the peritoneum anywhere would promote healing as well.

Antoine Lembert, in 1826, established the law of apposing the peritoneal surfaces in suturing wounds of the intestine. This was the first great step in the progress of intestinal surgery, and followed observation of nature's method of closing perforations by peritoneal adhesions and a deposit of lymph. The principle of approximating the peritoneum first established by Lembert opened a new field for gastro-intestinal surgery.

That the healing of the peritoneum may be by direct transformation of the deposit of lymph into connective tissue without the intermediate state of granulation tissue formation has been demonstrated by Hertzler. If there is infection, however, the healing must be by granulation, and not by this direct transformation.

Suturing is the method now chiefly relied upon in closing gastric and intestinal wounds. The Murphy button which was formerly extensively used and is now occasionally employed by some surgeons taught us much about the healing of these wounds. The principle of gentle and continuous pressure between two apposed peritoneal surfaces was well demonstrated by the action of the Murphy button. It leaves an excellent scar and the suture which can simulate these conditions may be expected to give satisfactory results. Gradual necrosis by the McGraw ligature may still have a small field. This is similar in general principles to the working of the Murphy button, as continuous pressure is kept up by a rubber cord inserted as a loop from one hollow viscus to the other. In this way a gastro-enterostomy can be done, or a lateral anastomosis. Such a method is always uncertain and could not be used in an emergency because it requires several days for the pressure to cut through and produce a sufficiently open communication. In the reëstablishment of the lumen of the intestine after an artificial anus continuous pressure is applied by inserting one blade of a forceps into one limb of the bowel forming the artificial anus and the other blade into the other limb and clamping them.

In suturing the stomach or intestine Lembert's principle of approximation of the peritoneal surfaces should always be followed. This, however, is merely one of the essential things for successful suturing. Halsted has

shown that it is necessary for a safe intestinal suture to catch some of the tough submucosa of the intestine, and Connell has pointed out that this layer is so thin that in order to be sure to catch the submucosa it is necessary for the needle to penetrate the mucosa. A safe suture, then, may be said to be one which penetrates the whole thickness of the bowel wall. Over this may be laid more superficial stitches, but they should not be counted upon as the chief holding sutures. In the stomach the mechanical conditions are such as to make necessary a somewhat different method of suturing from that employed in the intestine. The thick walls of the stomach, the heavy muscular coat and the lack of pliability render it essential to use at least two rows of sutures in every stomach wound. The great vascularity of the stomach also demands attention in seeing that all the bleeding points are properly controlled.

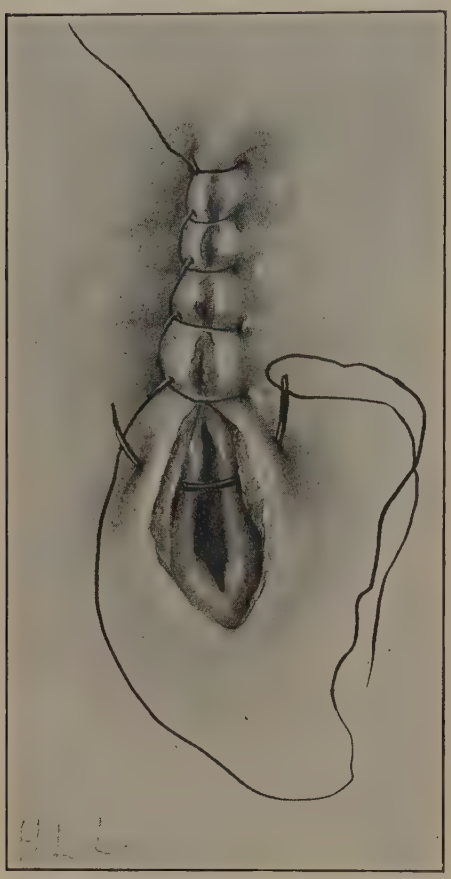

FIG. 34.—THE WOUND IN THE STOMACH IS BEING SUTURED WITH A CONTINUOUS LOCKSTITCH OF TANNED CATGUT.

Note that the needle does not include the mucosa, and that no effort is made to invert the margins of the wound. The reasons for this are explained in the text.

The work of Dragstedt is very suggestive in showing that it is important not to catch the pyloric portion of the gastric mucosa in the grasp of the suture if it can be avoided. He has demonstrated that one of the most satisfactory methods of establishing an experimental peptic ulcer in the pyloric portion of the stomach of a dog is to insert sutures in the mucosa at one given spot. Further toward the cardiac side ulcers are more difficult to create. The vast majority of peptic ulcers occur in the mucosa of the duodenum or of that portion of the stomach which normally secretes an alkaline fluid. The secretion of the pyloric portion of the stomach is distinctly alkaline. In a "sleeve" resection or in V-shaped excision of an ulcer in the body of the stomach, the same indication for avoiding the inclusion of the mucosa in the grip of the suture does not hold; but if the bleeding can be otherwise well controlled it would be wise even in this situation to avoid the mucosa as much as possible, or at least to take a very small bite of the mucosa. In gastroenterostomy the portion of the gastric mucosa that is affected is the acid-secreting part and it is difficult to make satisfactory hemostasis near the greater border of the stomach without catching some of the mucosa. In a midline

incision, such as in pyloroplasty, at the pylorus, including the pyloric mucosa in the suture can with care be avoided and at the same time bleeding can be controlled (Fig. 34). When the incision approaches either the greater or lesser curvature, where the vessels are larger, it may be necessary to include some of the mucosa at these points. In suturing the stomach it is well to use catgut sutures instead of linen or silk. Chromic or tanned catgut that will resist absorption for a period of about ten days is safer than plain catgut. This means that the catgut should resist absorption in muscle or connective tissue for at least three times this period, or for at least thirty days, for when the digestive action of the stomach plays upon the sutures the absorption is quite rapid. In many clinics linen and silk are used instead of catgut and with excellent results.

FIG. 35.—THE FIRST ROW OF SUTURES HAS BEEN COMPLETED AND THE SECOND ROW IS BEING INSERTED AS A CONTINUOUS RIGHT-ANGLE SUTURE APPROXIMATING THE PERITONEUM AND BURYING THE FIRST ROW.

We must consider the physiologic function of the various portions of the stomach in applying different types of sutures. Where the secretion is alkaline or where the resistance is somewhat lowered by establishing an unphysiologic condition, as in gastro-enterostomy, nonabsorbable sutures should not, as a rule, be used. In a gastro-enterostomy the acid gastric juice flowing into the lumen of the jejunum whose contents are alkaline so changes the conditions and lowers the local resistance that a nonabsorbable suture, which might be put up with by the tissues in a normal condition, may prove a source of too much irritation when the resistance has been lowered by establishing an unphysiologic situation. Nonabsorbable sutures would also seem inadvisable in a portion of the stomach which secretes alkaline material where ulcers are prone to occur.

No effort should be made to invert any of the stomach wall except by the last layer of sutures. Because the mucosa is unusually vascular in the body

of the stomach or in the curvatures, where the blood-vessels are large, it may seem wise to include the mucosa in the suture, which can be done by through-and-through sutures of the whole thickness of the gastric wall. If there is an unusually thick wall the first row of sutures had best be confined to the mucosa and submucosa alone and a separate row used for the muscular and peritoneal coat. The sutures cannot be very well hemostatic and at the same time accurately approximate the peritoneum. A continuous mattress suture will turn in the raw surface and approximate the peritoneum, but opposite each bite of the suture is a small portion of the stomach wall on which no pressure is made and from which bleeding may occur. A simple continuous suture, however, or a continuous lockstitch when the sutures are fairly close together, will not only approximate the tissues but make even pressure and so secure hemostasis.

When the stomach wall is sutured without clamps the bleeding may make the wound somewhat untidy, but it enables the operator to see where the bleeding is and to control it accurately. If the margins of a gastric wound are sutured while clamps are applied, the clamps should be slightly loosened at intervals in order to permit arterial circulation to come through and demonstrate any bleeding spots. This also serves to help the nutrition of the tissues just as has been spoken of regarding self-retaining retractors. A clamp may not only injure the delicate mucosa, but there is also the objection that the nutrition to the tissues in the blood supply is stopped during the application of the clamp. This is not always a serious consideration because the tissues usually have sufficient resistance to withstand it, but in patients who are quite ill every possible precaution for safety should be taken (Figs. 34, 35).

The approximating hemostatic suture is buried by a continuous right-angle or mattress suture of 00 tanned catgut. The bite of the needle is taken parallel with the incision, for in this way the loop of the suture will hold firmly and will not tend to cut out as would the ordinary running stitch in which the bite is taken at right angles to the general direction of the wound. In this latter suture tension is concentrated at the point in the bite of the suture farthest from the wound, whereas in a continuous mattress stitch the loop of thread maintains the tension about equally, and so does not tend to cut out.

When the gastrocolic or gastrohepatic omentum or any peritoneal covered fat can be readily brought over the sutured wound without too much tension, it may be fastened over the line of sutures with a few interrupted stitches of tanned catgut. These sutures should not catch the tag of omentum as a ligature, because in this way all of the nutrition to the tag is cut off, but should pierce it, taking a small bite for fixation and leaving the rest of it unconstricted with unimpaired nutrition. At the extremities of the wound the strain is greatest and here an additional interrupted mattress suture may be placed. No wound in the stomach or intestines should be sutured unless the margins can be approximated without tension. If tension exists the sutures will probably pull out or cut through, and perforation may occur. The tissues are approximated just accurately enough to give hemostasis and coaptation. The wound when sutured should not be white along the stitches, though when

making the suture snug the tissues in its bite may be white when first approximated. After the suture line has been nearly completed any areas in which there is too much constriction as shown by blanching of the tissues should be relieved by readjusting the sutures. This, of course, applies to the external row of sutures, not the inner or hemostatic row which must necessarily be tight.

The practice of attempting to invert the margins of the wound with each of many rows of sutures turns in a large mass of the stomach wall and imposes an additional burden upon the tissues, not only for repair of the unnecessary amount of stomach wall that has been turned in, but also for the absorption of an unusual amount of suture material. Whenever the mucosa is grasped in a suture sufficiently tightly to approximate it snugly, the mucosa sloughs. This is true not only of the mucosa of the stomach but of the intestine. Halsted's studies showed, as other experimental studies had demonstrated, that one of the first changes in a gastro-enterostomy is the sloughing off of the mucosa within the grasp of the sutures. The erroneous idea that sutures may be so placed in the gastric mucosa that the wound in the rest of the wall of the stomach will be permanently protected from the gastric juice does not take into account the universal sloughing off of the margins of the mucosa included in the continuous suture. This, however, takes a period of several days, and in the meantime the tissues beneath this mass have become infiltrated and acquired resistance to infections and to some extent to the irritation of the gastric or intestinal contents.

It is readily seen, then, that it is useless to trim off the crushed margins of the stump of the stomach after resection. Such a crushed band of the gastric wall occurs after the use of Payr clamps. As the whole thickness of the stomach wall is usually included in the sutures in a resection it is obvious that after trimming off this crushed area the mucosa caught in the sutures will slough. Preserving the crushed area also helps hemostasis. It will separate with the margin of sutured mucosa.

In suturing the whole thickness of the stomach wall a medium-size round needle and No. 1 tanned or chromic catgut should be used. This stouter catgut not only holds better but resists longer the action of the gastric juice and there is less tendency for it to cut through at any one point. A larger size catgut is unnecessary. The peritoneum with the superficial muscular coat is turned in with a finer suture material, as 00 tanned catgut.

In suturing the intestine it must be recalled that there is a very marked difference in the physiologic function and in the intestinal contents between the upper small intestine and the lower small intestine. In the duodenum Brunner's glands occur, which are not found in the small intestine elsewhere, but the two most important features to be considered are the contents of the intestine and the peristalsis. Gastric juice with high acidity has a very strong antiseptic effect and the gastric contents where there is practically normal gastric juice contain very few bacteria. The contents of the duodenum and the upper small intestine also contain very few bacteria, so that the spilling of the contents of the stomach and upper small intestine,

if immediately cleaned away, is usually not a serious matter, though it should be avoided if possible. On the contrary, the lower ileum teems with bacteria, and the slightest soiling by the contents of the ileum or colon may cause peritonitis.

The blood and lymph supply of the upper small intestine is also much greater than in the lower small intestine and the colon. This makes for rapid repair. The difference in the peristalsis, which Alvarez has pointed out and which has been described in a previous chapter, is important. In the upper jejunum the rhythmical contraction is about 20 to 24 per minute, whereas it is about half that amount in the lower ileum. The consequence is that there is greater activity in the upper small bowel and there is more constant motion. In the injured tissues there should be rest in order to heal satisfactorily. Peristaltic rushes occur at irregular intervals, are quite different from the rhythmic movements, and seem to gather momentum as they travel down the intestine. These rushes are usually inhibited for some time by trauma and only occur normally at very infrequent intervals. The problems in suturing the upper small intestine and the lower small intestine or colon are seen, then, to be different not only because of the bowel contents, but on account of the different nature of the peristalsis. It also takes less pressure on the lumen to produce obstruction in the upper small bowel than in the lower (Dragstedt). It is well known that obstruction in the upper small intestine is much more serious and more rapidly fatal than in the lower bowel. The causes of this are not fully known but the probable reasons are discussed in the chapter on intestinal obstruction.

It is evident that great care must be taken in suturing the upper bowel to avoid obstructing the lumen. As the contents are very low in bacteria there need not be the extreme caution about opening this intestinal lumen provided the neighboring peritoneum is well walled off with gauze. The bleeding points should, of course, be secured, but it is essential to see that the suture not only secures a good hold but that the diaphragm turned in will not materially lessen the lumen of the bowel at the resected area.

The suture should, of course, approximate the tissues snugly, but should never be tied too tightly. The bleeding may best be controlled by separate ligatures or by whipping over the bleeding points with catgut in a needle. If the oozing is extensive along the margins of the wound a continuous catgut suture is placed. As a rule, however, there are only a few bleeding points which are readily controlled by the usual methods of clamping and tying. All wounds of the upper small intestine should be sutured in such a way as to preserve the normal caliber of the bowel. It is often permissible to bend over a loop of intestine along the free border in a somewhat kinked form in order to make a satisfactory suture without narrowing the lumen.

If a loop of bowel has been seriously macerated or strangulated the possibility of obstruction must be borne in mind. If the bowel is not resected it might be well to make a lateral anastomosis around the injured area, after being satisfied that there will be no leakage at the point of injury. This will tend to permit peristalsis to continue without going through a bruised or macerated

loop and has distinct advantages in early restoration of peristalsis. Among other causes of death that have been advanced for obstruction in the small bowel, especially in the upper small bowel, is that the absence of peristalsis in late obstruction permits stagnation of the portal circulation and consequently has an injurious effect upon the function of the liver. Whether this be true or not, it is certain that the portal circulation and the lymphatic drainage from the bowel depend chiefly for its motive power upon the rhythmic contraction of the intestine.

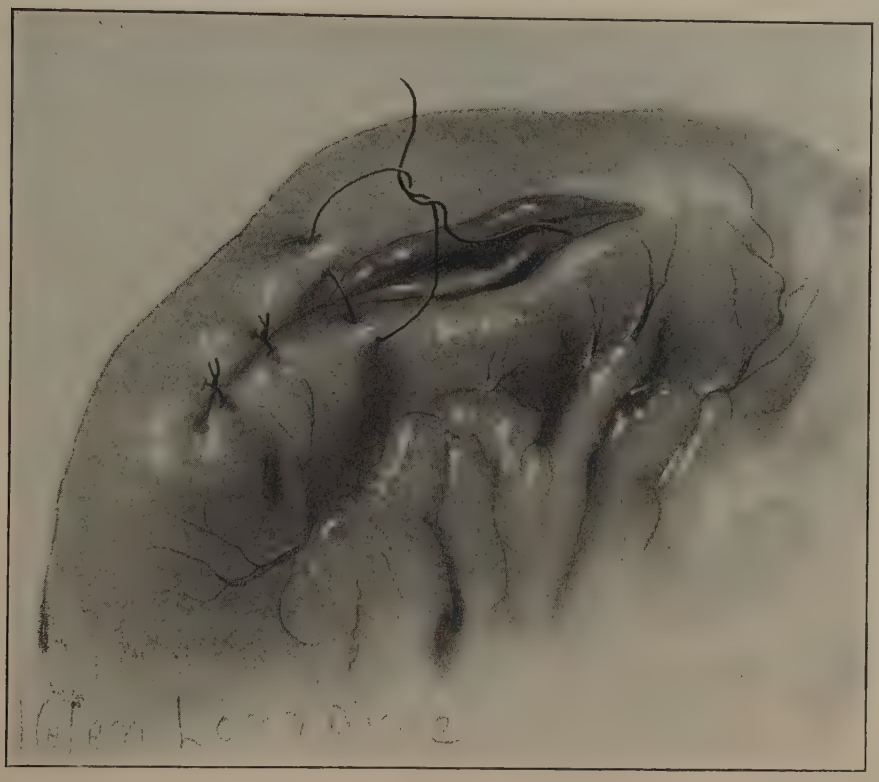

FIG. 36.—THE APPLICATION OF SIMPLE INTERRUPTED SUTURES APPROXIMATING THE PERITONEUM.

In suturing the small bowel linen or silk makes a satisfactory material. It usually works into the lumen of the bowel and is discarded. Chromic or tanned catgut may be used, but when the tissues are thin and there is only one layer of sutures, the swelling of the catgut as it absorbs moisture may tend to increase the constriction of the tissues within the grasp of the suture or sometimes may cause the knot to unravel. At any rate, where there is no tendency for peptic ulcers to form, nonabsorbable sutures seem to be well suited.

The methods of suturing the intestine are classed in a general way as interrupted and continuous. In many instances interrupted sutures are more desirable and in short and irregular wounds it is the only method that can be

satisfactorily applied. These sutures may be simple interrupted sutures (Fig. 36), turning in margins of the wound so as to approximate the peritoneum, or better still mattress interrupted sutures, used so extensively by the late Professor W. S. Halsted of Johns Hopkins (Fig. 37). This suture is placed by taking a bite with the needle as in the simple interrupted suture, first on one side and then on the other, leaving a small portion of the margin of the intestinal wound to be turned in as a diaphragm; but instead of tying the suture as a simple interrupted suture the needle goes back in a reversed direction. This makes four bites with the needle and when the suture is tied the knot is to one side of the approximated wound of the intestine and does not lie immediately over the incision. In the modified mattress suture, which can be placed more rapidly, a bite is taken with the needle parallel with the intestinal wound on one side and in a reverse direction on the other (Fig 38). Here the knot lies immediately over the incision. The advantage of a mattress suture is that the tension of the suture is distributed equally on the tissue within its grasp and not concentrated at any one particular point as in the simple interrupted suture. This not only gives a better grasp upon the tissues but the even approximation of the tension insures that the suture will hold longer than it would if the tension were concentrated at two small points. When the tissues are normal and firm, however, the ordinary interrupted sutures will hold satisfactorily if not tied too tightly.

FIG. 37.—THE APPLICATION OF THE INTERRUPTED MATTRESS SUTURES OF HALSTED.

The important point in intestinal sutures is not to tie them too tightly. In experimental work by students there is a great tendency to tie the sutures too tightly in order to avoid a leak. When this is done and the suture penetrates into the mucosa, which it should do, very frequently a leak occurs just at this point because the suture is so tight that it acts practically as a seton, destroying the tissues within its grasp and causing a perforation.

A continuous suture may be a lockstitch, a continuous overhand suture, or a continuous mattress or right-angle suture. The continuous overhand stitch is very useful, and when the tissues are firm and a good bite can be secured it is quite satisfactory. As a rule, however, the continuous right-

angle or mattress suture secures a better grasp of the tissues and less of the suture material is exposed on the peritoneal surface. A continuous lockstitch is valuable when suturing on the inside of the intestine where there is bleeding and it is desired to use the suture chiefly as a hemostatic stitch. The knot is a point of irritation and a potential point of leakage, not only because it makes an aggregation of suture material at this point, but because the knot may be tied so tightly that it causes necrosis. It is a valuable point in the technic of intestinal suturing to bury the knot if this can be easily done. It can be accomplished as a rule by first thrusting the needle in the reverse direction

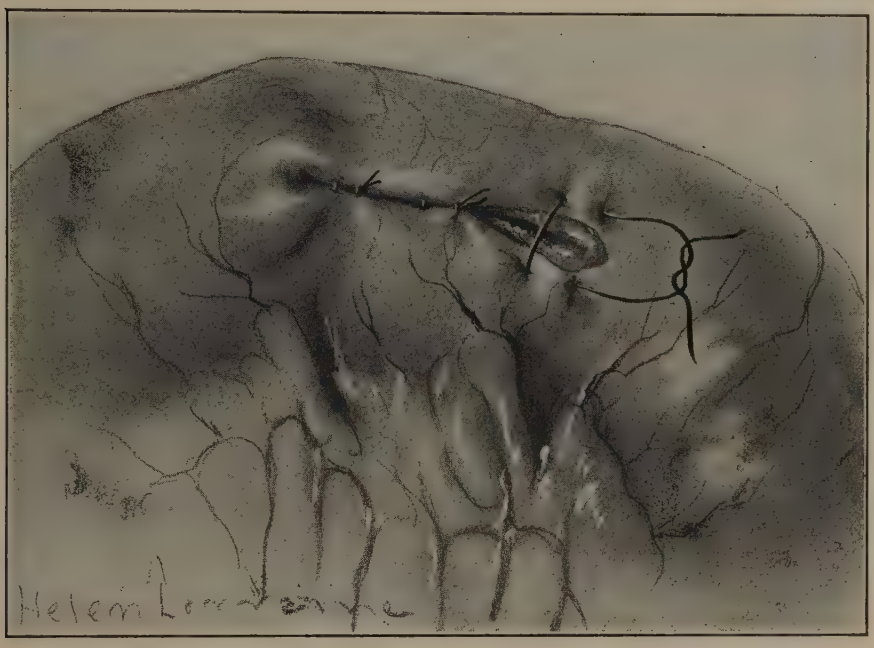

FIG. 38.—THE APPLICATION OF MODIFIED INTERRUPTED MATTRESS SUTURES. In this type of suture the knot lies over the incision.

from which the line of sutures is intended to be carried. The second bite of the needle goes in the direction in which the sutures are to be placed. The suture is tied, the short end is cut short, and with one or two back-sutures the knot can be buried (Fig. 39).

If the continuous right-angle suture is used, which is a good suture for routine use in the intestine, it is well to take a backstitch about every third or fourth suture in order to lock the suture at this point and prevent it from doubling up like a purse-string suture if pulled too tightly. This is a very real danger and especially in suturing after resection of the upper small intestine, for if an assistant handles the suture and is not careful about the tension it is quite possible to draw a continuous mattress suture so tightly that when it is tied the lumen of the bowel may be greatly constricted. By the backstitch about every third or fourth stitch, however, the accurate approxi-

mation that has been made is locked and cannot be altered by traction on the suture after the backstitch has been placed.

When the suture is to be terminated the needle should take a rather large bite in the tissues going outward from the line of sutures while the short end of the suture in the needle is pulled back longer. The needle is returned in a somewhat reverse direction, but the point is inserted in such a manner that the suture is carried at almost a right angle to the thrust of the needle just preceding this last bite (Fig. 40). When the suture is tied down snugly and cut short it tends to bury the knot, for it makes to some extent a purse-string effect.

If there is doubt about the suture line a neighboring piece of omentum can be fastened over the line of sutures with a few interrupted stitches.

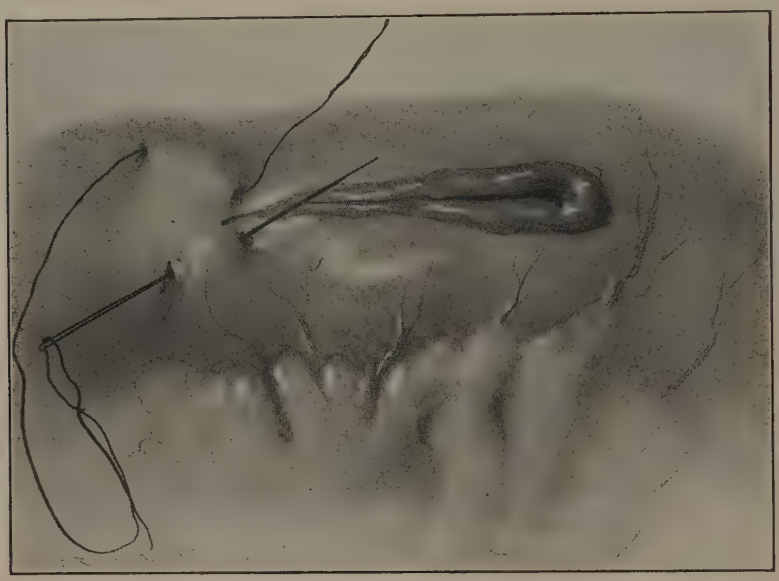

FIG. 39.—THE BEGINNING OF A CONTINUOUS SUTURE.
When the knot is tied it is buried because of the manner in which the suture has been taken.

Ordinarily this is not necessary and tends to promote adhesions, but if the suturing must be done through tissue that is inflamed or extensively injured, this precaution is very wise. A free graft of omentum is not as satisfactory as a portion of the omentum which has a normal blood supply. If the omentum is not available a loop of neighboring bowel may be sutured over the wound. Care should be taken that this does not produce kinking of the loop too near the point of suturing. It has been advocated to strip up a flap of peritoneum near the mesentery, though such a procedure of course leaves a raw surface in the mesentery which it is sometimes difficult to close. The adjoining mesentery may be used. In many instances in suturing a loop of bowel when there is inflammatory infiltration and doubt about the sutures holding, the loop can be brought to the parietal peritoneum and fixed with a few stitches. If

the margin of the parietal peritoneum along the wound is mobilized to some extent it can be more accurately applied to the injured bowel and at the same time the nutrition of the parietal peritoneum is not materially impaired.

When mesentery has been torn from the bowel the nutrition of the intestine is of course affected. The circulation in the intestine is not entirely terminal, as was formerly thought, but if the injury to the mesentery is along the border of the bowel the nutrition of the affected segment of the intestine will undoubtedly be greatly impaired. Whether resection in such instances is indicated depends somewhat upon the extent of the injury to the mesentery. Experi-

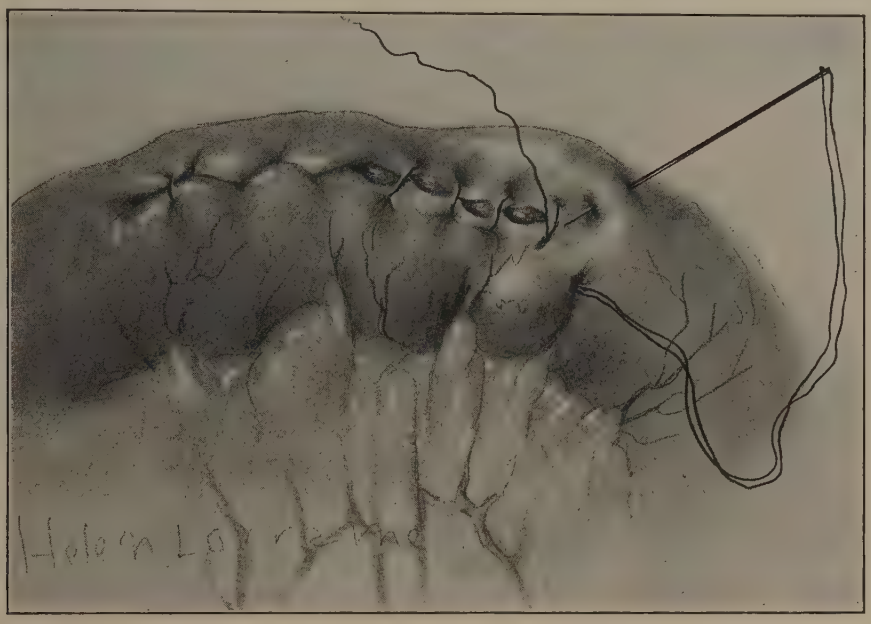

FIG. 40.—THE CONTINUOUS RIGHT-ANGLE SUTURE HAS BEEN COMPLETED, THOUGH THE LAST FEW STITCHES HAVE NOT BEEN DRAWN SNUGLY IN ORDER TO SHOW THE MANNER OF THEIR APPLICATION.

It is well to take a backstitch about every third or fourth suture in order to lock the sutures. The last knot is about to be tied. Note the direction in which the needle has been thrust so that when the knot is tied it will be partially or completely covered by the peritoneum. The knot at the beginning of the suture shown in the previous illustration is completely buried.

mentally it has been found in the dog that the intestine may be deprived of its mesenteric attachment for a distance up to 4 inches (10.1 cm.) and will survive if it is carefully wrapped around with omentum. The omentum quickly forms adhesions and gives a lymph and blood supply that seems to be sufficient. When the mesentery is separated from the bowel for a distance of more than 4 inches (10.1 cm.), however, gangrene usually ensues. It would be a helpful procedure when the mesentery is torn from the bowel for a distance of 1 or 2 inches (2.5 or 5 cm.) to suture the mesentery back to the bowel and at the same time to cover this segment of intestine with omentum. This segment will doubtless not function for some

days, and it might be wise to do an enterostomy with a rubber catheter after the method described on pages 293 through 297 in the bowel immediately above the injured portion. These procedures are not indicated when the patient is in good general condition and when the surgeon has a satisfactory and confident technic of resecting and suturing intestine. In occasional cases, however, when there is great need of haste and the patient's condition is poor, and particularly if the surgeon's technic in intestinal suturing is not satisfactory, stitching back the mesentery and covering the injured bowel with the omentum as has been described may be a wise and really a life-saving procedure.

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## CHAPTER VII

## CONGENITAL PYLORIC STENOSIS; PTOSIS OF THE STOMACH

### CONGENITAL PYLORIC STENOSIS

The etiology of congenital pyloric stenosis is not definitely known. That it is truly congenital in at least some of the cases seems to be proved by the fact that Cautley recognized the condition in the seventh month of fetal life. It was believed by Holt and others that the hypertrophy is the essential lesion and the spasm is only secondary. Other theories maintain that the spasm is the original cause and that this produces the hypertrophy. Alvarez has suggested that a lack of sympathetic nervous control may cause overaction of the muscles along the pyloric portion of the stomach with resulting hypertrophy. None of these views has been definitely established.

The growth itself is a firm whitish tumor of cartilaginous consistency and oval in shape. It occupies the region of the pyloric canal, which anatomists recognize in the adult as being the terminal 1¼ inches (3 cm.) of the pyloric portion of the stomach. This canal is normally more prominent in infants, and its chief constituent is a circular muscular layer. The enlargement stops abruptly at the beginning of the duodenum and terminates almost equally abruptly on the stomach side. Dean Lewis has called attention to the folding in and compression of the mucous membrane by the hypertrophied circular fibers, and demonstrated this postmortem. The blood supply always is deficient, and in some instances it seems to be exceedingly scant.

Congenital pyloric stenosis occurs about three to four times more frequently in males than in females, and an interesting feature is that a large number of these infant patients are the first-born. It is often found in breast-fed babies. Symptoms usually appear from two to four weeks after birth. The first symptom is constant vomiting which later becomes forcible. As the disease progresses and weight is lost, peristalsis of the stomach is easily observed through the thin abdominal wall. Sometimes two or more waves of peristalsis can be seen at the same time. In many cases a firm olive-shaped mass can be felt in the right hypochondriac or in the right epigastric region, but in others when the duodenum is attached closely under the liver it is impossible to palpate a tumor. The palpation of the tumor is not essential for the diagnosis, but along with other symptoms makes it almost positive. There is, of course, constipation because but little material passes through the stomach into the bowel.

Roentgenologic study is usually not essential to diagnosis, though many diagnosticians value it very highly. In cases of doubtful diagnosis from clinical symptoms roentgenologic examination with the fluoroscope is valuable.

Spasm of the pylorus is often difficult to differentiate from congenital pyloric stenosis, but is usually accompanied by more intestinal upset and the spasm can often be quickly overcome by the administration of atropin, giving from 1/50 to 1/24 grn. in 24 hours. Sometimes this may be increased to 1/16 grn. in 24 hours. This is given in 1:1000 solution, beginning with one drop and is increased rapidly until there is a marked effect, such as flushing, mydriasis, and dryness.

The treatment for congenital pyloric stenosis is not always clear. There are two groups of extremists. One group believes that all cases of this disease should be operated upon, while the other thinks that all should be treated medically without operation. As usual, the truth doubtless lies between these two extremes. All cases should, if seen early enough, receive medical treatment first. If, after a proper diet with the administration of atropin up to the toxic limit, the child continues to lose weight for five or six consecutive days, operation should doubtless be done. In no instance, however, should operation be the primary treatment in the beginning of the disease. Competent medical treatment, particularly careful regulation of the feeding for such cases, should not only be instituted before operation but continued after it.

With the large percentage of successful results in considerable groups of cases reported by Downes of New York, Strauss of Chicago, and Roland Hill of St. Louis, the chief objection to operation, which is the mortality, is greatly diminished. When operative treatment was first recommended for these patients it consisted of posterior gastro-enterostomy. Such a procedure in an emaciated and weakened infant, necessitating a long incision, considerable exposure of the abdominal contents and complete relaxation of the abdominal muscles, was a very formidable procedure and the mortality rate was high. The jejunum in these infants is very small and the technic for the operation is so difficult in such diminutive viscera as to make the operative procedure seem of quite a different nature from gastro-enterostomy in adults. Some surgeons have actually suggested having an entirely new set of instruments made for such cases—a kind of doll-baby set adapted to the small tissues.

Fredet advised a division of the hypertrophied muscle fibers. In 1913 Rammstedt brought this operation to the attention of the medical profession more prominently. The operation merely consists in thoroughly dividing the circular muscle fibers of the pyloric canal, taking care not to injure the mucosa either of the stomach or of the duodenum, particularly of the duodenum. There have been many modifications of this simple procedure, but a simple operation that is equally effective is much more desirable than a complicated technic.

Strauss, of Chicago, isolates the mucosa of the pyloric canal from its muscular surrounding and then splits off a flap from the hypertrophied muscle, turning it on one of the attached margins as a hinge so as to cover the released mucosa. Theoretically, this may seem desirable and Strauss' mortality rate has been low. These results, however, do not differ materially from the recent results of Downes and others who have had a large series of cases and have employed the simple Rammstedt-Fredet method. The splitting of the muscular

flap may serve to cover the mucosa, but it is doubtful if the muscular flap functions as muscle. The exposed gastric submucosa and mucosa which bulge into the wound seem thin, but if the operation is properly performed a blood-vessel of any size is rarely injured, so the mucosa is well supplied with blood.

These operations call for great gentleness. As has been pointed out in the chapter on anatomy, the transition between the mucosa of the stomach and the mucosa of the duodenum is very sharp. The sudden widening of the caliber of the duodenum from the mucosa of the pyloric sphincter causes a bulging which with thin muscular layer makes an injury to the duodenal mucosa in dividing the muscle of the pyloric canal peculiarly likely to occur.

The bulging up of the mucosa of the duodenum can be partly obviated by depressing the duodenum, but with the naturally very thin muscular wall of this bowel the mucosa may often be reached before it is anticipated. Formerly it was recommended that an incision be made in the stomach and a sound passed into the duodenum in order to insure patency. This, however, is quite unnecessary, adds materially to the danger of the operation, and has justly been abandoned. It is important, of course, to free the mucosa in the pyloric canal and to leave no constricting band, but even after this is done the symptoms sometimes persist for a few days and it often requires very skillful dieting and management by a pediatrist in order to carry the patient through these critical days. If the surgeon is positive that he has removed the constricting bands, reliance should be placed solely upon the medical treatment.

Two of the great dangers in these babies are dehydration and lack of carbohydrates. These should be avoided by hypodermoclysis of glucose solution. The 5 per cent glucose solution recommended by Matas, of New Orleans, is very effective and may be given slowly. It takes a very small amount, however, to distend the skin of these dehydrated infants. In very ill babies an intravenous infusion of 5 per cent glucose in the external jugular vein or in the longitudinal sinus may be indicated, or the glucose solution may be injected intraperitoneally. A transfusion of whole blood will often serve even better, though, as a rule, the glucose is all that is necessary and will usually tide over the period between the operation and the time when the stomach can be safely given the proper amount of nourishing fluid.

One of the most important features of the operative procedure in these cases is the anesthetic. If these babies are given ether it adds greatly to the risk. They struggle unless rather profoundly anesthetized, and if the incision is made at all large and the intestines are extruded the danger is increased.

I have found that the most satisfactory anesthesia is a local anesthetic and a sugar rag. The sugar rag was first used in this work by Stuart McGuire, of Richmond. It is prepared in the usual way well-known to nurses, and should not be too large. The desired quantity of butter and sugar, thoroughly mixed, is wrapped in a soft piece of linen. This should be given the baby as soon as he is placed on the table. After disinfecting the abdominal wall

the site of the operation is well infiltrated with ½ per cent procain solution, preferably made up in fresh Ringer's solution, to which about two drops of 1:1000 adrenalin solution have been added to each ounce. This should be used freely and massaged gently so as to facilitate absorption. If the tumor is palpable, the incision is made through the upper right rectus muscle immediately over the tumor. If it is not palpable, it is made through the inner portion of the right rectus a short distance above the navel. An incision one and one-half inches (3.8 cm.) long is usually sufficient. A long incision adds to the complications, not only by affording opportunity for extrusion of the abdominal contents but by causing a larger wound that is subject to tension when the baby cries. An incision of one and a half inches is sufficiently large through which to introduce the finger and to palpate the pyloric end of the stomach. Special instruments have been devised for retractors and for delivery of the hypertrophied pylorus, but they seem unnecessary. Special instruments that are not essential to any operation carry a great handicap. With small blunt retractors or a medium-size Crile retractor the abdominal incision can be stretched so that the anterior wall of the stomach appears. If the enlarged pylorus does not readily appear in the wound the anterior surface of the stomach, preferably along the greater curvature, is caught with mosquito forceps, taking care to do as little damage as possible and to catch tissue in which there are no large blood-vessels. By a kind of "hand-over-hand" manipulation the stomach is gradually delivered into the wound until the proximal portion of the enlarged pylorus comes into view. The mesenteric attachments are then grasped more firmly and the pylorus is caught between the finger and thumb. A longitudinal incision is made in the hypertrophied pylorus with a sharp knife, going only through the peritoneum and the superficial fibers of the enlargement. The rest of the incision is deepened with the handle of the knife. The muscle fibers are brittle and will break and tear easily. If the dissection is carried to the mucosa with a knife there is a possibility of injuring the mucosa or dividing some blood-vessel that may cause an annoying hemorrhage (Fig. 41).

FIG. 41.—THE MUCOSA IS EXPOSED AND IS SEPARATED FROM THE MUSCULAR COAT BY BLUNT DISSECTION WITH THE HANDLE OF A KNIFE OR BY SPREADING SCISSORS DISSECTION ALONG THE MARGIN OF THE INCISION. If the margins of the incision are too forcibly pulled apart the traction may injure the mucosa.

When the mucosa of the pylorus appears, the margins of the incision are undermined by blunt dissection with the handle of the knife or spreading scissors dissection, *i.e.*, by inserting blunt-pointed scissors closed and opening them widely. If the margins are pulled apart too forcibly the mucosa may be

torn—an accident which has happened in my experience. If there are any remaining constricting bands they are broken with the handle of the knife. This division should be carefully but thoroughly made, and the mucosa separated from the inner layers of the hypertrophied pylorus almost entirely around the pyloric canal. Particular care must be taken that there are no constricting fibers about the pyloric sphincter. It is in this region that injury to the mucosa of the duodenum is likely to occur. There is usually some oozing. This is best controlled by firm pressure with dry gauze for about two minutes. If it persists the bleeding point is whipped over with fine plain catgut in a fine curved needle, or a neighboring tag of peritoneal covered fat, either from the great omentum or from the adjacent borders of the stomach, is sutured over the wound.

If the duodenal mucosa has been accidentally opened it should be promptly sutured, preferably with fine silk or with fine tanned catgut. This is accurately applied, but without too much tension. It is difficult to invert sufficient tissue here to carry out the principle of Lembert, but if the margins of the wound in the mucosa are accurately approximated with interrupted sutures not tied too tightly, the ends of the sutures can be passed through a tag of omentum so as to bring this peritoneal-covered fat over the wound. If the configuration of the duodenum is such as to permit infolding without too much constriction, the ordinary technic of intestinal suturing may be utilized. It must be recalled, however, that any unnecessary infolding or trauma in this region will probably be a retarding influence on the establishment of peristalsis. If the operation has been completed and there is no unusual bleeding, a tag of peritoneal-covered fat either from the great omentum or preferably from the adjacent borders of the stomach may be fastened over the exposed mucosa with a few interrupted sutures of fine catgut. This seems to give to the operator an added sense of security and comfort, but if there has been no perforation and no unusual bleeding it probably does not materially increase the chances of recovery.

If the baby's condition is very critical, it might be wise to insert into the lower duodenum through a fine hypodermic needle several ounces of a solution of 5 per cent glucose in Ringer's solution before closing the abdomen.

The abdomen is closed with two or three through-and-through sutures of coarse silkworm-gut. It is essential to stop all bleeding points in the abdominal wall either by catching and tying them in the ordinary manner or, if the muscle persists in oozing, by whipping over the bleeding area with fine plain catgut. Every drop of blood unnecessarily lost in these emaciated babies increases the risk. The skin may be more accurately approximated with fine sutures of silk or tanned catgut. A snug dressing is applied with adhesive plaster. Lowndes Peple, of Richmond, has called attention to the fact that this constriction should not be too tightly placed as it may produce pressure which will interfere with peristalsis.

A careful feeding should be instituted, beginning in small quantities immediately after the operation. The sutures are removed in about two weeks.

## PTOSIS OF THE STOMACH

Ptosis of the stomach is often merely a part of a general ptosis in which the supporting structures of the stomach and other abdominal viscera are not competent to retain them in what is called a normal anatomical position. It is unusual to find marked ptosis of the stomach unassociated with a more or less general visceroptosis, and it is impossible for ptosis of the stomach to occur without some falling down of the transverse colon. The symptoms are frequently vague and indefinite, and have been described in the chapter on diagnosis. In many cases actual ptosis of the stomach may exist to a considerable extent without causing symptoms, and when symptoms do appear it is by no means certain to which of the ptosed viscera they may be due. A stomach whose lower border is almost in the pelvis may function satisfactorily, while on the other hand a lesser degree of ptosis may produce in the duodenum or pylorus a mechanical obstruction that interferes with emptying. Cases of gastroptosis should be studied carefully by the internist and by the surgeon to determine the most effective method of treatment. If a satisfactory regimen of diet with abdominal support relieves the symptoms there seems no indication for an operation. When ptosis is general and causes symptoms, the prolapsed colon and cecum are often in greater need of attention in order to cure the patient than is the stomach itself. Operations to correct these defects have been described in a monograph by R. C. Coffey. When, however, symptoms do occur and other causes have been reasonably well eliminated, when roentgenologic examination shows a delayed emptying of the stomach due to a kink or a water-trap at the pyloric end of the stomach or at the duodenum, operation should be done.

We should bear in mind that the object of any operation should be to eliminate pathologic conditions and restore physiologic function. It does not seem that a gastro-enterostomy fills these indications. The operation of Coffey for ptosis of the transverse colon also elevates the stomach. In his method the gastrocolic omentum is sutured to the parietal peritoneum of the anterior abdominal wall in a transverse line a short distance above the umbilicus. This is done with interrupted sutures of silk or linen or tanned catgut and serves to elevate both the stomach and the colon. Care should be taken to carry the sutures as far out on each side as possible. There are many excellent results from this operation. Frequently, however, when the transverse colon itself must be elevated there is even stronger indication for fixing the cecum and ascending colon. The conditions which we are considering are those in which ptosis of the stomach is the chief factor. The attachments resulting from this suturing to the anterior parietal peritoneum are usually firm and stable, as described by Coffey in experimental work, but occasionally cause discomfort, particularly in the early days of convalescence. The creation of such an artificial attachment may, at least theoretically, hinder the normal movement of the stomach. Many of these patients are inclined to be neurotic and doubtless unconsciously exaggerate the symptoms, but a small percentage of them complain of discomfort after this operation.

The more complicated and extensive procedures, such as the technic of Rovsing and others who carry a series of sutures through the anterior wall of the stomach and fasten them to the abdominal wall are far more objectionable than the operation of Coffey. Plication of the stomach does no good in ptosis and is not a satisfactory operation even in chronic dilatation. Any one who has followed the roentgenologic examination of the stomach or is

FIG. 42.—A LINEN OR SILK SUTURE IS INSERTED INTO THE GASTROHEPATIC OMENTUM AFTER THE MANNER OF A PURSE-STRING SUTURE.

It is tied snugly as the stomach is shoved up. If necessary this may be reinforced by another suture of the same material.

interested in the modern physiologic studies of its motor function can readily appreciate that the strong expulsive peristaltic waves of the pyloric half of the stomach must produce great traction and intermittent tension on that portion of the gastric wall firmly attached to the abdominal wall. When we recall that comparatively slight adhesions at the pylorus and the duodenum may produce marked symptoms, we can recognize the unwisdom of firmly fixing such a mobile viscus as the stomach to the anterior abdominal wall.

The most satisfactory operation for ptosis of the stomach when such a

procedure is indicated is to attempt to strengthen and shorten its normal anatomical support. This is the gastrohepatic omentum. The gastrohepatic omentum is particularly weak and frail in its center, just opposite the region at which the stomach is most dependent.

The operation of Beyea was founded in general on the correct principle of shortening this broad ligament, but unfortunately it does not add material strength to fold over the frailest portion of the gastrohepatic ligament on itself. A series of interrupted sutures, or even one row of interrupted sutures, placed in this region involves considerable manipulation and some difficulties in technic.

The requisite shortening of the gastrohepatic omentum can usually be done by the simple procedure of a single purse-string suture. This should be linen or silk and begins on the left of the midline at the lesser curvature of the stomach in the thicker part of the gastrohepatic omentum. The second bite is taken high up under the liver well on the left side near one of the larger vessels, because here the tissue seems to be somewhat stouter. The suture is carried across the midline to the right side and catches a bite in the stronger portion of the gastrohepatic omentum high up under the liver. The fourth bite is taken in the gastrohepatic omentum along the lesser curvature of the stomach near the pylorus (Fig. 42). The suture should be long and the ends are drawn up and tied gradually while the stomach is pushed up under the diaphragm. The ends of the suture are tied snugly so that there can be no kink in it but not too tightly because the suture may tear out. After tying them several times the ends are cut short. If there seems to be occasion for an additional purse-string suture or for an interrupted suture to reinforce this original suture it can be placed, but usually a single purse-string suture is sufficient. By this method the stouter margins of the gastrohepatic ligament are not only brought together from above downward but laterally, so that the weak central portion of the ligament is practically eliminated. Then, too, the presence of some unabsorbable ligature, such as linen and silk, doubtless causes a reaction around it which strengthens the ligament.

By this operation the normal ligament is utilized for upholding the stomach without resorting to artificial fixation or to any procedure that will interfere with normal gastric peristalsis. If, in addition to the ptosis, there is also a kink at the pyloric end of the stomach or the duodenum, it should be corrected by appropriate technic. If the sphincter is spastic it may be divided according to the technic of pyloroplasty described on page 173, but this is not often necessary.

Frequently with gastric ptosis there are indications for support of the transverse colon, which is accomplished by plicating the gastrocolic omentum with a series of interrupted sutures of linen or silk, extending from the splenic flexure of the colon to the hepatic flexure.

The abdominal wound should be closed in such a way as to produce no constriction and, if possible, to increase the space in the epigastric region. Sometimes a flap of fascia from the rectus muscle on one side is outlined and folded over and fastened to the margins of the incision on the other side.

This gives an increase of space though such a procedure is not always necessary. Accurate approximation of the peritoneum and fascia with interrupted through-and-through sutures of silkworm-gut, between which may be placed interrupted sutures of tanned catgut going only through the fascia and peritoneum, is usually sufficient, but in extreme cases with a narrow costal margin the utilization of a flap of the anterior wall of the rectus muscle is indicated.

In the after-treatment the foot of the bed is elevated to prevent traction on the sutured gastrohepatic omentum. Small meals at frequent intervals will cause less discomfort and will produce less strain on the stomach than larger meals taken at long intervals.

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# CHAPTER VIII

## CARDIOSPASM; GASTROTOMY; GASTROSTOMY

### CARDIOSPASM

The etiology of cardiospasm is obscure. It apparently is due to spasm of the sphincter of the terminal esophagus. Whether the spasm is from local irritation or is a reflex condition has not been determined. The researches of Hunter and Royle, of Sydney, Australia, and of H. B. Devine of Melbourne, on the sympathetic nervous supply may throw some light on this problem. It is well known that contraction of the sphincters is under the sympathetic system, and it seems probable that, according to their theory, an improper balance between the sympathetic supply to the sphincteric muscles and the motor supply to the muscles above the sphincter may cause an unbalance which is responsible for this condition.

After cardiospasm has existed for some time there become marked dilatation and organic changes in the esophagus above the site of the cardiospasm resembling in a general way the dilatation of the colon in Hirschsphung's disease which, according to the theories of the Australian investigators, is similar in its underlying factors.

If one recalls the possibility of a large pouch of the esophagus and bears in mind the difficulty in swallowing solid food and the regurgitation of food taken many hours before with apparent absence of gastric juice, the probability of the existence of cardiospasm in a patient presenting these symptoms becomes great. Roentgenologic examination, particularly with the fluoroscope, makes the diagnosis positive. Cardiospasm can usually be differentiated from obstructions of an organic nature, such as stricture or cancer that occur in the terminal esophagus, by the fact that in cardiospasm an esophageal bougie may be passed, whereas in organic obstruction there is difficulty in passing a sound. This rule does not always hold, however, for in a case of mine (Fig. 43) there was a decided kink so that it was impossible to introduce the stomach tube or a bougie.

The best routine treatment for cardiospasm that has so far been devised is the method of Plummer which consists in dilatation. A specially constructed tube with a collapsible bag over its end is introduced through the esophagus until the collapsed bag is within the grasp of the cardiac sphincter. The tube is then filled with water under definite pressure so that the sphincter is forcibly stretched. This procedure is not entirely free from danger, though if properly used with a series of treatments it is successful in most cases. With a careful technic its efficiency is increased and the small amount of danger that accompanies it is diminished. The danger consists chiefly in too much

pressure in the first few applications so that there may be some laceration of tissues producing shock or hemorrhage. The treatments must be repeated at intervals and the results should be checked by occasional roentgenologic examinations under the fluoroscope.

There are exceptional cases in which because of kinking of the lower end of the esophagus the tube cannot be readily passed. Watts, of the University of Virginia, made an anastomosis between the terminal portion of the esophagus below the diaphragm and the cardiac portion of the stomach—a cardioplasty. The eventual clinical result was very satisfactory and the enormous dilatation of the esophagus was greatly diminished. The technic of such an operation must depend upon the local conditions, particularly upon the length and availability of that portion of the esophagus below the diaphragm. The technic employed by Watts consisted largely of the application of the steps of Finney's pyloroplasty to the cardiac sphincter. There was a considerable projection of the esophagus into the abdominal cavity, and the bulging of the esophagus just below the diaphragm and the cardia was rather readily accessible. An incision 4 cm. (1.5 inches) in length was made with the center of the incision at the junction of the esophagus and the cardiac end of the stomach. The tissues on each side were approximated with sutures after the manner of a Finney pyloroplasty, so that the margin of the wound in the esophagus was united to the margin of the wound in the stomach on the corresponding side. The last report from the patient, a little more than a year after the operation, showed very marked improvement with considerable gain in weight, and the roentgenogram recorded a decided shrinking of the esophagus with a large opening in the cardia and a well-filled stomach.

Fig. 43.—Roentgenogram of Cardiospasm Showing a Marked Kink and the Impossibility of Passing a Stomach Tube.

In a case of mine in which it was impossible to introduce an instrument into the stomach from the esophagus I operated, intending to follow the procedure of Watts. A glance at the roentgenogram (Fig. 43) shows why it was impossible to introduce a bougie or stomach tube. Possibly a bougie could have been introduced with the esophagoscope, but as it would have been necessary to carry out a series of treatments, which was impractical in this case, it was thought that a single operation which might correct the condition would be preferable. An incision was made from the ensiform cartilage along the inner portion of the left rectus muscle to about the level of the navel. As the patient was rather thin, the exposure was not very difficult. The

peritoneal layers around the terminal esophagus were divided, which mobilized the esophagus to some extent, but instead of finding a redundant bulging esophagus, as roentgenologic observation seemed to indicate, the terminal esophagus was about normal size. The portion of the esophagus beneath the diaphragm was too short and too small to make it possible to perform the cardioplasty of Watts. The stomach was opened just below the cardiac sphincter. A finger was inserted into the terminal esophagus and met no obstruction or any unusual constriction. It was then thought best to dilate the sphincter thoroughly and leave within the grasp of the cardiac sphincter a large soft rubber tube to stay as long as possible.

FIG. 44.—DIAGRAM SHOWING THE APPLICATION OF A LARGE RUBBER TUBE IN THE CASE OF CARDIOSPASM REFERRED TO IN THE PRECEDING FIGURE.

The duodenal tube passes through the larger tube, in order to furnish nourishment and at the same time to give the dilated esophagus rest by abolishing the necessity of deglutition.

The cardiac sphincter and the terminal portion of the esophagus were thoroughly dilated by inserting uterine dressing forceps and opening the blades as much as possible. In this way two fingers could be introduced through the cardiac sphincter and the lower portion of the esophagus. A soft rubber catheter was passed around the esophagus just as it entered the stomach. This was not tied, but the ends were clamped together and traction upon the catheter made better exposure and materially facilitated the operation. As a stomach tube could not be introduced into the stomach from above, it was passed into the esophagus from within the stomach, hoping that it would appear in the pharynx and mouth. The esophageal pouch was so large, however, that the tube merely curled up within the esophagus and did not appear in the pharynx. A stomach tube was then passed from the mouth as far down as possible. It curled up in the dilated esophagus but a loop of it was seized with a long forceps introduced through the incision in the stomach and the tube was pulled down. Two stout silk cords were fastened to the end of the stomach tube, which was then withdrawn through the mouth. A duodenal tube was tied to one of the cords, drawn down from the mouth into the stomach, and then passed through a large soft rubber tube 10 cm. (4 inches) long and 2 cm. in diameter. The gastric end of the other of the two silk cords was threaded in a needle and passed through the upper end of this large rubber tube and tied. The large

tube was adjusted into the lower end of the esophagus, so that it projected about a half inch (1.3 cm.) into the stomach (Fig. 44). The end of the duodenal tube, passing through the large rubber tube, was left in the stomach. The lower margin of the large tube was fastened to the gastric mucosa with a single catgut suture. This was done to hold it in position for at least a few days and to prevent its displacement by vomiting that might occur after the operation. The wound in the stomach was closed with layers of catgut sutures and some peritoneal covered fat in the neighborhood was brought over to reinforce the superficial layer of sutures. The abdominal wound was closed without drainage.

Since the conditions made it impossible to perform the operation of Watts, the indications seemed to be to dilate thoroughly the cardiac sphincter and the terminal portion of the esophagus and to keep within the grasp of this sphincter a large soft rubber tube, which would not fit tightly enough to cause necrosis but would be sufficiently large to prevent marked contraction of the cardiac sphincter. In a similar manner, the effects of divulsion of the sphincter ani are more prolonged if a large tube is left within the grasp of this sphincter for a few days after the divulsion. The large tube would also promote drainage of the dilated esophagus into the stomach and so encourage contraction of the esophagus. The object of the duodenal tube was to keep the patient nourished without having to swallow, and so give additional rest to the tissues involved.

FIG. 45.—ROENTGENOGRAM OF CARDIOSPASM SHOWN IN THE TWO PRECEDING ILLUSTRATIONS.

This was taken about two months after operation. The report of Dr. Fred M. Hodges shows that there is still some dilatation of the esophagus, but it is emptying very much better than before operation.

The patient made a satisfactory immediate recovery. The large tube became displaced after a few days and was removed fourteen days after the operation by pulling on the silk cord which emerged from the mouth and had been fastened to the cheek with adhesive. The duodenal tube was removed five days later as it began to cause some irritation. The patient left the hospital thirty-two days after admission and was able to swallow moderately soft food with comfort. When heard from two months after operation, December, 1924, she was doing well, was gaining in weight, and could readily swallow soft food. It is too early yet to pronounce the patient cured, and recently there has been some recurrence of the original symptoms (Fig. 45).

If in such a case there is a recurrence and satisfactory treatment under the esophagoscope is not available, a temporary gastrostomy might be considered, introducing stout silk cords from the gastrostomy wound to the mouth and pulling down with one of the cords a folded rubber tube after the manner suggested by Ochsner for stricture of the esophagus.

## GASTROTOMY

The operation of gastrotomy may be indicated to remove foreign bodies or to excise pedunculated benign tumors of the stomach. It was formerly a practice to remove ulcers of the posterior wall of the stomach through an incision in the anterior wall. This, however, results in suturing the posterior gastric wall from within the lumen of the stomach and as the exposure is not always satisfactory the suturing is often inaccurate. Much mucosa is embraced in the sutures, and in this manner a necrosis may occur with a recurrence and probably an extension of the ulcer. In a patient of mine in whom I did a gastrotomy and removed an ulcer in the posterior gastric wall in 1918 there was rapid recurrence of the ulcer following necrosis of the tissues within the grasp of the sutures that were placed from within the stomach. The recurrent ulcer reached the lesser curvature of the stomach and involved a large blood-vessel from which the patient had massive hemorrhages, and died on the twenty-first day after operation. Since then I have abandoned gastrotomy for treating ulcers within the stomach.

Pedunculated tumors, as myomas or adenofibromas, that sometimes occur in the stomach, especially about the pyloric portion, may be excised through a gastrotomy. The pedicle of the tumor is tied and the tumor removed. If the growth is sessile and the mucosa over it is intact and in good condition it would be better to remove the tumor through an external incision over it and if possible shell it out without opening the mucosa, rather than to incise the mucosa and remove the tumor from within the stomach. The introduction of sutures in the mucosa of the pyloric end of the stomach may occasionally result in an ulcer. The work of Dragstedt and Vaughn, in showing that the most satisfactory way of producing an experimental ulcer in the pyloric mucosa of a dog is to insert a number of sutures, should be borne in mind. If the mucosa over the benign tumor is greatly thinned out or is ulcerated it would doubtless be better to excise a portion of this redundant mucosa along with the growth. After carefully controlling the bleeding the mucosa is united preferably by suturing the submucosa with fine tanned catgut after the manner of a subcuticular suture. With a long and narrow pedicle, however, which can be controlled by a simple ligature, the danger of ulcer formation following the slight trauma of the mucosa involved in the pedicle by the application of the ligature should be reduced to a minimum.

Occasionally there are multiple papillomata in the stomach which can be treated only by excision of the portion of the gastric wall involved. There is no typical operation for this, but the general principles of gastric surgery and of suturing described in the preceding chapters should be followed.

Extraction of foreign bodies is probably the most frequent cause for gastrotomy. The ingestion of glass, nails, and other small pieces of hardware is not infrequent in asylums for the insane, and there are individuals who in the performance of the vaudeville stunts of swallowing nails or broken glass find that these substances do not always pass out of the stomach but may accumulate. One of the most interesting occasions for gastrotomy is a

hair-ball. This occurs sometimes in the insane and sometimes in women whose mentality is normal, but who make a practice of chewing the ends of their hair. Matas, of New Orleans, and A. M. Willis, of Richmond, have reported interesting cases of hair-ball in the stomach. In these cases there was a large, smooth, palpable tumor in the epigastric region. Roentgenologic examination of a hair-ball is rather typical. If barium is given as in ordinary gastro-intestinal roentgenologic study it shows chiefly around the outline of the hair-ball.

In gastrotomy the incision is made that will give full access to the foreign body or tumor to be removed. Other things being equal, it is best to make an incision about the middle portion of the anterior wall of the stomach. A longitudinal incision will involve fewer large blood-vessels and can be readily closed. It also is more capable of being extended so as to give a wider exposure. Unless it is necessary in order to gain proper access the incision should not be carried over the pyloric portion of the stomach because of the possibility of a resulting peptic ulcer from the sutured area of the mucosa. Stomach clamps are usually not necessary. The length and position of the incision is determined, the stomach is caught with Allis forceps at the proposed ends of the incision, lifted up and opened. It is best to carry the incision only down to the mucosa at first, so that all bleeding vessels can be recognized and clamped before the mucosa is opened. In this manner unnecessary injury to the mucosa is avoided. Immediately after incising the gastric mucosa a tube connected with a suction apparatus removes the gas and liquid contents in the stomach. The incision should be long enough to permit extraction of a foreign body or a tumor without undue traction or injury to the wall of the stomach. It is much better to have a clean-cut incision in the gastric wall for an additional inch than to have traumatized margins of the incision, particularly of the gastric mucosa.

In closing the wound the mucosa may be sutured with a separate layer of fine tanned catgut if the incision has not involved the pyloric mucosa. It is better practice, however, to place no sutures in the gastric mucous membrane, but to approximate the submucosa with a fine suture that will include the small bleeding vessels and at the same time will project the gastric mucosa into the cavity of the stomach as a flange, acting somewhat as a valve to protect the underlying structures. Another row of coarser tanned or chromic catgut is placed approximating the peritoneal and muscular coats after the manner of a continuous suture without any effort to invert the tissues. The last and superficial line of sutures is of 00 tanned catgut and is inserted as a right-angle continuous suture which completely buries the preceding layer and approximates the peritoneum after the principle of the Lembert suture. If the line of sutures is unusually long a few additional interrupted mattress sutures may be placed. If the incision has been made transverse instead of longitudinal the peritoneal covered fat from the adjacent gastrohepatic or gastrocolic omenta may be stitched over the line of sutures as an additional protection.

As to the after-treatment of gastrotomy the general principles of after-treatment of gastric operations are followed. Care should be taken to prevent distention of the stomach and to give physiologic rest by avoiding food for

at least three or four days, though water may be given in small quantities. It is also good practice to lavage the stomach twice a day for one or two days in order to relieve gaseous distention and to remove the gastric juice and mucus that often occur as a result of irritation after incision into the stomach.

## GASTROSTOMY

Gastrostomy is for feeding, and its indications are stricture of the esophagus or a growth involving the esophagus or the cardiac end of the stomach. There are many technics for this procedure which varies to a large extent according to the local conditions.

If the stomach is large and dilated a pouch of the stomach may be drawn up after the manner of the S. Franck operation, though this is usually not

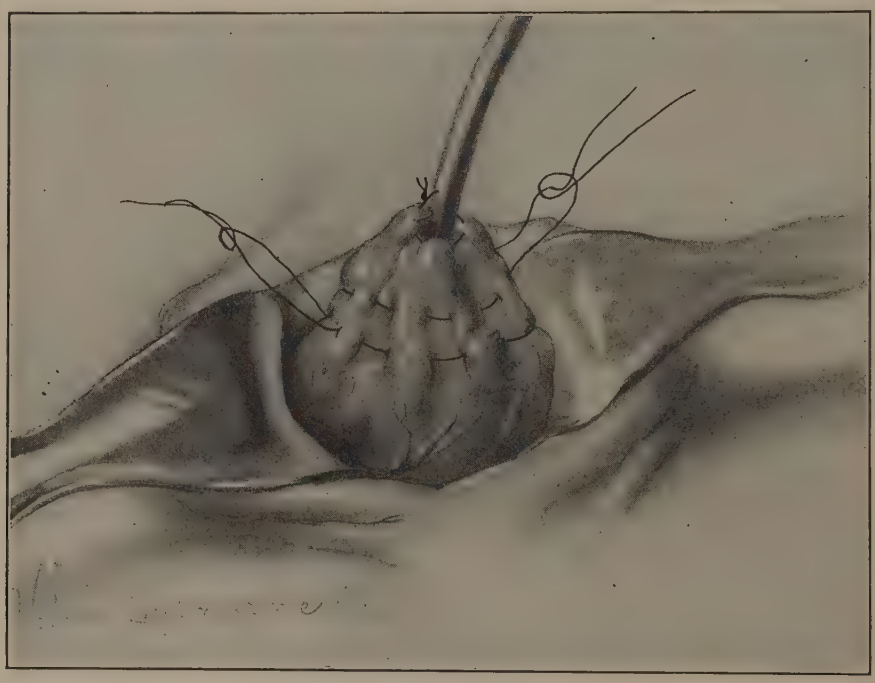

FIG. 46.—SENN'S GASTROSTOMY.

The tube has been inserted in the stomach, fastened, and transfixed with a purse-string suture. Other purse-string sutures are applied.

necessary for satisfactory control. According to the Franck operation, an incision is made along the outer border of the left rectus muscle extending from the costal cartilage downward for about 3 inches (7.7 cm.). The anterior gastric wall is exposed and brought up into the wound. If the stomach is greatly dilated a cone is made by catching the anterior wall of the stomach at such a point as will render the cone most easily deliverable into the abdominal incision. A second shorter incision about 2 inches (5 cm.) long is made over the costal cartilages 2 inches (5 cm.) to the left of the original incision. The

subcuticular tissue between the second and the first incisions is undermined and the tip of the cone of the stomach is brought through this undermined portion and fastened with sutures. Unless the condition of the patient is desperate it is best to leave this cone in position for about three days, when it is opened, a tube inserted, and food introduced. A slight spring pressure over the strip of skin between these two incisions compresses the stomach sufficiently to prevent spilling of the gastric contents.

The indications for the Franck operation are infrequent because usually the stomach is not dilated but contracted and because, too, the necessity for wearing a spring pressure apparatus like a truss is just as disagreeable as the constant presence of a tube. The Senn method of gastrostomy consists in placing a purse-string suture into the anterior wall of the stomach, making an incision within its grasp, and inserting a tube. The tube is usually a medium or large-size soft rubber catheter. Additional purse-string sutures to

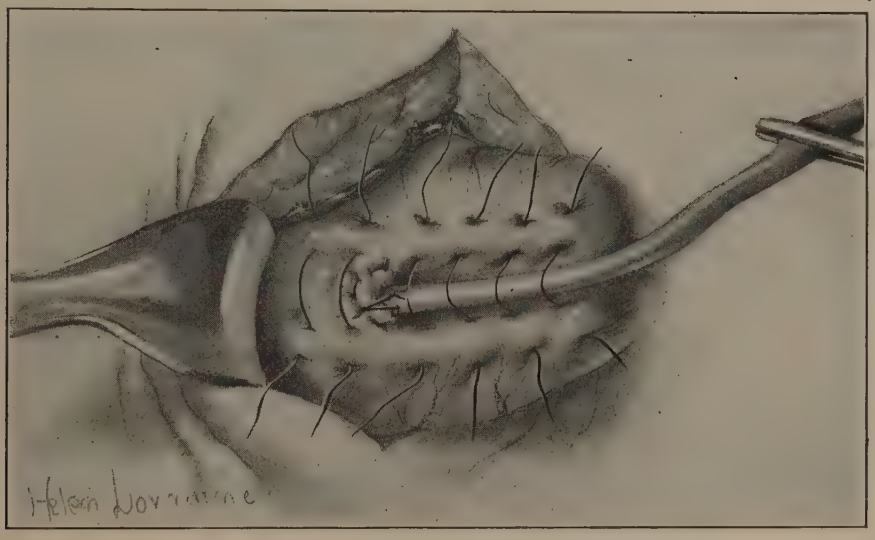

Fig. 47.—The Witzel Method of Gastrostomy.

The tube has been fastened in the stomach and is laid on the surface of the stomach. Interrupted sutures for burying the tube have been placed.

the number of three or four are inserted in a series so as to bury the tube still deeper and invert a cone of the stomach (Fig. 46). The anterior wall is then fastened to the parietal peritoneum of the abdominal wall with a few sutures. The tube should remain in position for at least a week, when the track will be sufficiently established for the tube to be withdrawn at intervals, cleansed, and reinserted. The tube is clamped after feeding, curled on the abdomen, and the patient is usually spared the annoyance of leaking from the gastric wound.

The method of Witzel is somewhat similar in principle to the method of Senn, but does not require the infolding of so much of the gastric wall. Consequently, it can be done more readily in the contracted stomach which often occurs when the operation of gastrostomy is indicated. Here a tube

is inserted in the anterior gastric wall about the middle of the stomach and somewhat nearer the pyloric portion than when the Senn gastrostomy is done. It is more desirable to have the tube near the cardiac end of the stomach, which is the natural point of entrance of food through the esophagus. This feature, however, is not a very important one. In the Witzel method the tube may be inserted pointing toward the cardiac end or to the pyloric end, depending to a large extent upon the shape and size of the stomach and its relation to the surrounding tissues. A purse-string suture is placed and an incision is made within the grasp of the suture. A medium-size soft rubber catheter is inserted through the incision and the suture tied as in the first

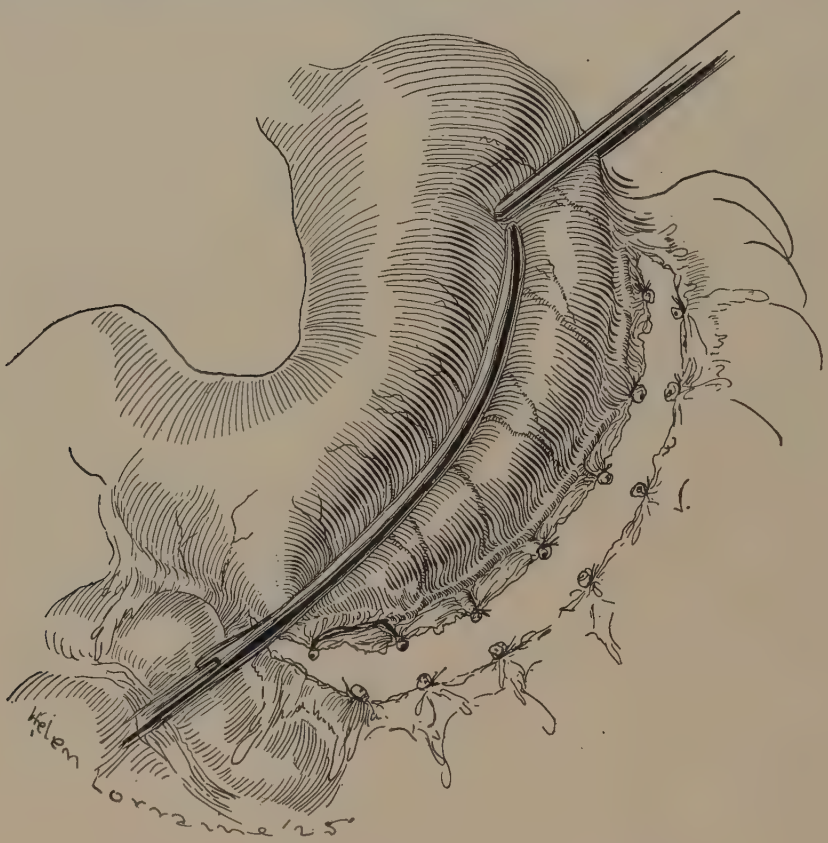

FIG. 48.—THE FIRST STAGE OF THE JIANU OPERATION.

The gastrocolic omentum has been severed, taking care to preserve the blood supply to the greater curvature of the stomach at the cardiac end. Soft-bladed clamps are applied.

step of the Senn operation. Instead of consecutive purse-string sutures, however, the tube is laid flat on the wall of the stomach for about 2.5 inches (6.4 cm.) and the wall of the stomach is sutured over the tube so that the tube lies in a furrow or groove converted into a tunnel by suturing the stomach wall over it. The tube emerges from the abdominal wound as after the Senn operation and the stomach is similarly fastened to the anterior parietal peritoneum (Fig. 47).

The incisions for these latter two operations are through the upper outer portion of the left rectus muscle and the tube comes out about the middle of the wound between the sutures.

After resection of the esophagus for cancer an effort may be made to fashion a gastrostomy opening which will be high up on the chest wall. The first successful case of excision of cancer of the esophagus was done by Franz Torek, of New York, in March, 1913. The esophagus was doubly ligated and divided in the lower portion of the thorax. The lower stump was inverted and buried with two successive purse-string sutures. The upper portion was mobilized, the esophagus brought out through an incision at the root of the neck, and the thoracic incision was closed. A transverse cut in

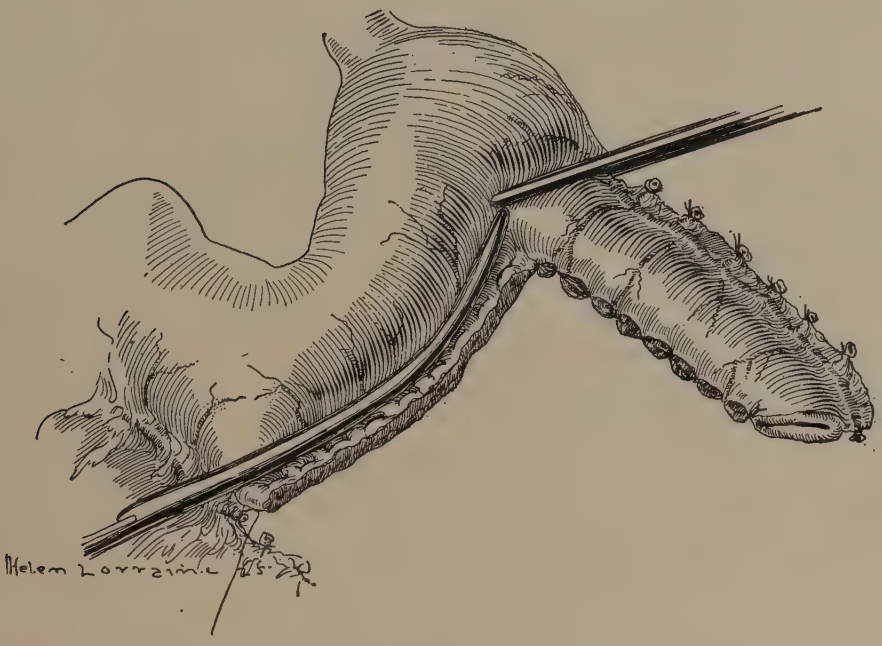

FIG. 49.—THE SECOND STAGE OF THE JIANU OPERATION.
The flap comprising the greater curvature of the stomach has been severed and partly sutured.

the skin of the chest was made over the second intercostal space where it seemed that the upper stump of the esophagus would lie after the cancer had been resected. The cancer was cut away and the upper stump of the esophagus was brought through the tunnel made by burrowing beneath the skin from the incision in the second intercostal space to that in the neck, and the wound in the neck was closed. An esophageal tube connected the stump of the esophagus to a gastrostomy wound, so that food went through the upper portion of the esophagus, the connecting tube, and then into the stomach through the gastrostomy.

A type of gastrostomy called the Jianu gastrostomy would in most instances more nearly approximate the channels of living tissue through which

the food would travel, leaving a comparatively short space to be bridged by a rubber tube. The Jianu gastrostomy, as shown in the illustrations, consists in converting the lower portion of the stomach along the greater curvature into a tube hinging at the cardiac end. This tube is brought through a subcutaneous tunnel, and may reach as far as the third rib. If the upper stump of the esophagus is sufficiently long it might be anastomosed to this plastic channel formed from the greater curvature of the stomach. The essential features in the construction of this tube consist first of all in a thorough exposure of the whole stomach through a long incision. The gastrocolic omentum is divided and tied about midway between the greater curvature of the stomach

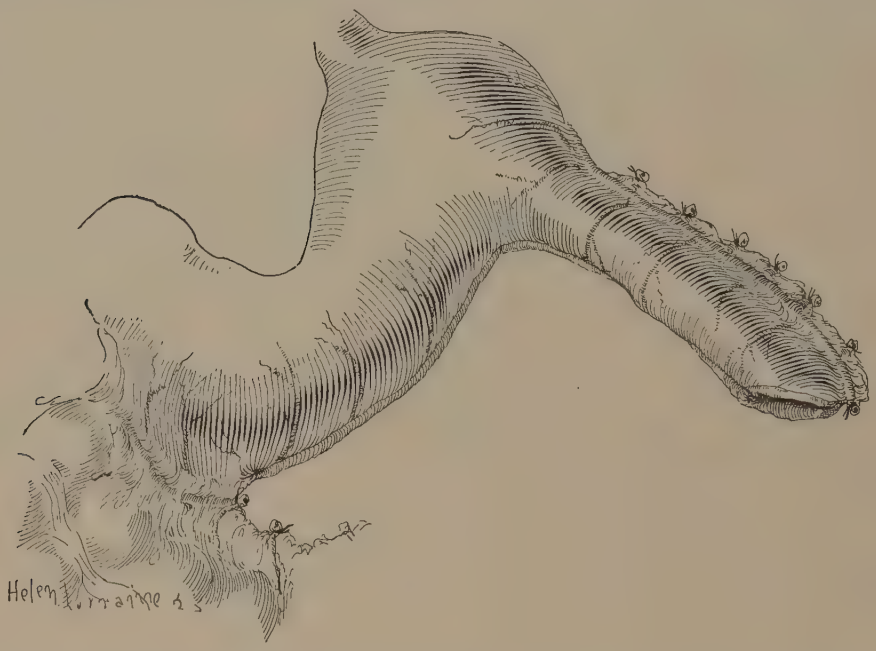

FIG. 50.—THE FIRST ROW OF SUTURES IS BURIED WITH A CONTINUOUS RIGHT-ANGLE SUTURE. A well-nourished tube constructed from the tissues along the greater curvature of the stomach is carried through a tunnel beneath the skin as shown in Fig. 51.

and the colon, taking care to preserve the gastro-epiploic arteries. The stomach is clamped longitudinally by a long soft clamp about midway between the greater and lesser curvatures. Near the cardiac portion a shorter clamp is placed which meets the long clamp and so isolates the lower portion of the stomach. The right gastro-epiploic artery is doubly clamped and divided at the pyloric portion of the stomach. An incision is made parallel with the greater curvature and at a sufficient distance from the greater curvature to insure a tube about an inch (2.5 cm.) in diameter after the suturing and infolding have been done. The circulation, which in this tube comes solely through the left gastro-epiploic artery, must be well preserved, as an injury to this artery will necessarily result in gangrene. The margins of the gastric flap

are turned in and sutured (Figs. 49, 50) with a double row of tanned catgut sutures. The inner row, which is a continuous hemostatic suture, includes the whole thickness of the stomach wall for as the clamp is applied it would be probably too dangerous not to include the mucosa for fear of hemorrhage after removal of the clamp. When the first row of sutures, which unites the cut surface, has been completed, a second row buries the first row and approximates the peritoneum as a continuous right-angle suture. The length of this tube is ascertained and the distance it will reach on the thorax is measured. In a patient of Willy Meyer the tube was found to reach to the third rib without tension. The tissues beneath the skin are burrowed through to this point with long forceps and an incision is made over the end of the forceps. After thoroughly dilating this tunnel to prevent undue later constriction the tube fashioned from the stomach is brought through it and fastened to the margins of the skin (Fig. 51).

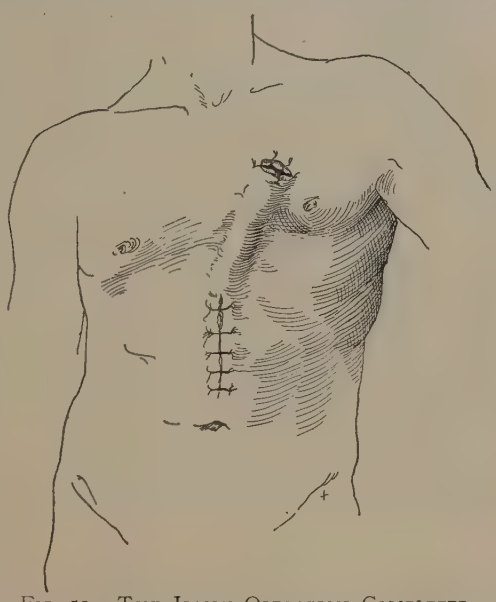

FIG. 51.—THE JIANU OPERATION COMPLETED.
The tube shown in the previous illustration is carried through a tunnel in the subcutaneous tissue and fastened to the margins of the incision in the skin.

If a resection of the esophagus is contemplated it is best to do the gastrostomy some time before operating upon the esophagus, so that the tissues may become accustomed to the gastrostomy opening and the patient can be satisfactorily nourished while giving the esophagus a rest. Later, after excising the esophageal cancer, union with the upper stump of the esophagus might be considered.

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# CHAPTER IX

## ULCERS OF THE STOMACH, DUODENUM, AND JEJUNUM

As there are so many points in common, peptic ulcers of the stomach may be considered with peptic ulcers of the duodenum. The symptomatology of peptic ulcers has been discussed in Chapter IV.

The etiology of gastric and duodenal ulcers has never been definitely determined, but some very interesting work by Rosenow, Mann and Williamson, Dragstedt, Ivy, T. B. Reeves, and others has thrown much light upon this subject. Reeves has shown that the blood-vessels in the pyloric portion of the stomach and in the first part of the duodenum have a very oblique course in the gastric and the duodenal walls. This makes them particularly susceptible to thrombosis and when considered in connection with the fact that the muscular layer of the pyloric portion of the stomach is very vigorous, the possibility of trauma to these long delicate vessels is obvious.

Rosenow showed that certain strains of streptococci had a marked affinity for the mucosa of the stomach and duodenum. He emphasized the importance of the rôle of focal infection which most commonly resides in the teeth, the tonsils, the appendix, or the gall-bladder.

Durante has demonstrated that a lesion of the nerve supply of the stomach may produce ulcer. It is possible, however, that this acts by constricting the vessels controlled by this nerve supply, and such an ulcer may be directly of vascular origin.

Mann and Williamson in some very interesting experimental work on peptic ulcers, diverted the alkaline secretion, which neutralizes the gastric juice as it leaves the stomach, to a portion of the intestine some distance below the point of emergence of the acid gastric juice. They found that "typical or chronic peptic ulcer, quite comparable pathologically to that found in man, developed in the intestinal mucosa, just adjacent to the gastric mucosa, in a high percentage of cases." Among these experiments was a series in which the duodenum was divided at the pyloric end of the stomach and was closed. The jejunum was severed some distance below its origin and the distal end of the severed jejunum was sutured to the pyloric end of the stomach and the upper end of the jejunum was united end-to-side to the ileum. These operations were done with great care, no intestinal clamps were used near the sutures, the bleeding was carefully checked, and 00 chromic catgut was employed for sutures. In 16 of the animals upon which this experiment was performed and which came to necropsy, 14 showed ulcers of the subacute or chronic type similar to peptic ulcers in the human being. These ulcers were usually in the jejunum a very short distance from the line of union of the jejunum to the stomach. Later Mann found that if the end of the jejunum

containing an ulcer was disconnected from the stomach and was sutured so as to form a blind pouch and the stomach was again united to the duodenum, the peptic ulcer in the jejunum quickly healed.

These experiments of Mann and Williamson are of great interest, not only in throwing some light upon the etiology of peptic ulcer—particularly the type known as jejunal ulcer that follows gastro-enterostomy—but also in indicating the tendency such ulcers have to heal if the irritating secretions are removed and the tissues containing the ulcer are given rest.

Dragstedt has shown that one of the most successful methods of producing an experimental peptic ulcer in a dog is by applying multiple sutures at one point in the pyloric mucosa. This frequently produces a lesion having the appearances of a peptic ulcer.

The general conclusion which may be drawn from the work of these and of other experimenters in the etiology of peptic ulcers is that there are doubtless many factors that may be responsible. In some cases the ulcer may be due to only one of these factors. In others, there may be a combination. Foci of infection undoubtedly have a prominent part and when treatment of an ulcer is undertaken the foci of infection should be removed wherever possible to do so. Occasionally these foci, aside from residing in the more common regions such as teeth, tonsils, appendix, and gall-bladder, may be found in the prostate and seminal vesicles in man, or in the tubes, ovaries, or uterus in woman.

The anatomical observations of Reeves may possibly account for the so-called affinity of the pyloric and duodenal mucosa for streptococci, for when these bacteria are being transported thrombi may be more readily formed in the long, delicate, tortuous vessels subject to the vigorous action of the pyloric muscles than elsewhere. Thus a favorable breeding ground for the streptococci is established. Doubtless some form of thrombosis, embolism, or vascular injury is one of the essentials for the formation of peptic ulcer, but that there are also other factors involved seems obvious. It is interesting that a large percentage of peptic ulcers arise in the mucosa that normally secretes alkaline material in close proximity to the acid-secreting mucosa of the stomach. The location of the majority of peptic ulcers is in the pyloric portion of the stomach, particularly along the lesser curvature, and in the first part of the duodenum. The mucosa of the pyloric portion of the stomach has an alkaline secretion and in view of Mann and Williamson's experiments it is very suggestive that the sudden physiologic change from the acid-secreting mucosa to an alkaline-secreting mucosa must be rather trying upon the latter type of tissue. This, in connection with greater activity of the muscles in the pyloric portion of the stomach, throws some light upon the causation of ulcer. While it is true that in the first part of the duodenum the musculature is not well developed, the mucosa here, which is an alkaline-secreting mucosa, is closely attached to the very active pyloric sphincter and doubtless this muscular action may have a sphere of influence over the first inch of the duodenum.

The symptoms of gastric and duodenal ulcer are usually quite similar

and have already been discussed. The symptoms of sudden perforation of a peptic ulcer are usually intense pain, profound shock, and great spasm over the abdominal muscles. These symptoms occurring suddenly in the upper abdomen point very strongly to perforation of a peptic ulcer or else to rupture of the gall-bladder. A slowly perforating ulcer may give merely localized pain and spasm which sometimes disappear. There may be, however, an atypical rupture, and such unusual cases must be borne in mind. This is best illustrated by citing a case that occurred in my practice.

Mr. A. K. P., aged 34, entered St. Elizabeth's Hospital on October 29, 1924. He was referred by his family doctor with symptoms of right kidney colic and with a history of having had rather sudden pain in the right lumbar region early that morning. A. I. Dodson, urologist to St. Elizabeth's, examined the patient cystoscopically, and, after taking roentgenograms of the renal pelvis, believed there was no stone and no renal cause for the pain. The patient had been vomiting and some of the vomitus was coffee-ground in color. The pain was in the region of the right kidney below the twelfth rib with slight muscular spasm in the right iliac fossa. There was no tenderness or spasm in the epigastric region. There was a history of recurrent attacks of pain from which he had recovered. They were not so severe as this attack but somewhat similar in character. There was no pain on urination. On account of the negative cystoscopic examination and the muscular spasm and pain in the right iliac fossa, an appendectomy was done two days after admission. The peritoneal cavity contained a moderately thick fluid which did not appear to be pus. The peritoneum around the mesentery of the ascending colon was swollen and edematous. The appendix, which was removed, was large and congested and on opening contained considerable pus. The pus was not foul, and while the mucosa was congested it was not perforated. Being unable to account for the symptoms and findings, but thinking it might be an unusual case of penetration of bacteria through the appendicular wall, I was content with the removal of the appendix and the placing of a drain. The following day the patient's condition was rather critical, with pulse 140. He was given intravenously large quantities of 5 per cent glucose as suggested by Matas, and improved considerably. The vomiting continued, however, frequently with coffee-ground material. After two days some of this material appeared from the drainage. As there was no indication of any break in the posterior parietal peritoneum at the time of operation, though it was swollen and edematous, it was difficult to account for the appearance of material in the wound similar to that from the vomitus. Finally, the skin became irritated, rather typical of drainage from the upper intestine or stomach, and dye administered orally appeared in the wound in about an hour.

The patient was again operated upon, under local anesthesia, six days after the appendectomy. The incision through the upper right rectus showed no sign of peritonitis in the region of the stomach or of the first portion of the duodenum. About 2 inches (5 cm.) from the pylorus there was a brawny mass in the posterior wall of the duodenum. This was held down by firm adhesions and was fixed beneath the cystic duct and the adjoining portion of

the gall-bladder. There were a few lymph flakes over the surface of the duodenum. The pyloric portion of the stomach was occluded with a stout kangaroo tendon, taking care not to interfere with the exudate and adhesions which were beneath the pylorus. A posterior gastro-enterostomy was then done without clamps.

The patient rallied somewhat, but gradually became increasingly toxic and died on the fourth day after operation. Necropsy showed an ulcer in the posterior wall of the duodenum about 2 inches (5 cm.) from the pylorus. The ulcer had a necrotic margin, was about an inch (2.5 cm.) in diameter, and had perforated into the retroperitoneal spaces. The right kidney was floating in a thick, dark, foul fluid which had also undermined the mesentery of the ascending colon and cecum. This fluid communicated through the mesentery of the cecum with the drainage tube inserted in the pelvis when the appendix was removed.

This case is reported at some length because it is unusual and represents a type of perforation of ulcer that may be easily misconstrued, for the symptoms were entirely different from the so-called classical cases of perforation of a duodenal ulcer and the irritation around the kidney produced marked renal symptoms.

The treatment of a perforated ulcer of the stomach or duodenum is to close the perforation promptly and with as little trauma as possible to the surrounding tissues. In the rare ulcers that perforate posteriorly in the duodenum it is usually impossible to close the ulcer. The common point for perforation is the anterior surface of the first inch (2.5 cm.) of the duodenum. Ulcers of the stomach frequently perforate posteriorly. The danger increases with delay. If operation is done soon after the perforation, the peritonitis is often merely chemical and the wound may frequently be closed without drainage. If there is bacterial infection the prognosis is grave and drainage should be instituted. Sometimes these perforated ulcers are small and may be easily sutured. Frequently the perforation is minute, but there is a broad indurated base. There can be no standard method of dealing with all perforated peptic ulcers. If the ulcer is not too large and is near the pylorus a pyloroplasty after the method described on page 173, with excision of the ulcer, is quickly performed and gives the advantage of not only excising the ulcer but of relieving the spasm at the pyloric end of the stomach and so promoting physiologic rest. If the ulcer has extensively infiltrated, and especially if there are numerous adhesions, it would be better to attempt to approximate the infiltrated margins of the tissue by gently inserting sutures of fine tanned catgut, and after tying the sutures leaving the ends long and passing them through adjacent tags of peritoneal covered fat, which may be obtained from the gastrohepatic omentum, the gastrocolic omentum, the round ligament of the liver or the greater omentum. By passing the suture through the fat instead of tying it around the tag as a ligature, the nutrition to the portion of the tag in immediate contact with the sutured ulcer is but slightly impaired and the additional nutrition promotes healing.

If the perforated ulcer is in the stomach and there is no marked infiltration

its disinfection by cautery, according to the method of Balfour, and closure in layers, superimposing adjacent peritoneal covered fat, is a satisfactory procedure. A small ulcer can be simply excised, but extensive operations, such as pylorectomies or sleeve resections, should rarely be done after an acute perforation, because not only is it more trying upon the patient but a larger raw surface is left for absorbing the septic or toxic products that may have been caused by the perforation.

FIG. 52.—DRAWING SHOWING OCCLUSION OF THE PYLORUS WITH KANGAROO TENDON.

This was made at necropsy of a patient in whom a gastro-enterostomy was done and the pyloric end of the stomach occluded with a stout kangaroo tendon for extensive infiltrating duodenal ulcer. The patient had a myocarditis, and while his immediate postoperative recovery was smooth he died rather suddenly of cardiac affection 48 hours after operation. Necropsy showed the abdominal condition satisfactory. Note that the tendon is partly buried by lymph deposit even in this short time.

With a large infiltrating ulcer in the duodenum or in the pyloric portion of the stomach near the pylorus dependence should not be placed solely upon the rather fragile closure made by suturing the infiltrated margins, and yet if the ulcer is large its excision beyond the areas of infiltration will sacrifice too much tissue to permit satisfactorily reëstablishing the channel. It is necessary in such cases to give physiologic rest by diverting the current of food. One of the simplest and most satisfactory methods is, after suturing the ulcer, to encircle the pyloric end of the stomach fairly close to the ulcer with a stout kangaroo tendon which is tied snugly enough to occlude the lumen but not to constrict the vessels unduly, tie it five or six times to avoid unraveling of the knots when the tendon absorbs water and swells, and do a posterior gastro-enterostomy.

It is unnecessary to bury the knots of the kangaroo tendon or to suture the stomach over it because if the tendon is not tied too tightly there is sufficient vascular supply for healing and abundant lymph from the lymphatics covers the tendon (Fig. 52). The posterior gastro-enterostomy is done according to the technic described on page 193, preferably without clamps.

In this manner the leak is stopped, physiologic rest is given, and by diverting the gastric contents pressure is relieved. Just how long a kangaroo tendon will occlude the pyloric portion of the stomach has not been definitely determined. Most experiments along this line have been made upon healthy animals and the ligature has often been tied very tightly. In such instances the ligature quickly cuts through and restoration of the channel results.

A ligature applied only snugly over tissue affected by the ulcer probably acts differently. In three cases in which the pylorus had been occluded by kangaroo tendon after the manner described, a gastro-enterostomy done, and the cases followed up afterwards, there has been apparently complete occlusion of the pylorus in one case ten months after operation, as determined by roentgenologic examination by plates and with the fluoroscope. Another case examined twenty-five days afterwards was almost occluded, and in the third case examined nineteen months afterwards the opening had been reëstablished almost to capacity. At any rate, the occlusion doubtless lasts for several days, and this is the critical period and gives the physiologic rest which the tissues so urgently need during this time.

In perforated ulcers in the posterior wall of the stomach access may be had by a transverse incision in the gastrohepatic omentum, in the gastrocolic omentum, or by an incision in both omenta. This may also be augmented by an incision through the transverse mesocolon after lifting up the transverse colon. It is best not to incise the stomach itself in perforations for reasons mentioned on page 158. After the ulcer of the posterior gastric wall has been excised or, if extensive, after it has been sutured without excision, it is wise to follow the suggestion of W. J. Mayo and bring through a rent in the mesocolon or in the gastrocolic omentum a portion of the great omentum and fasten it loosely to the posterior wall of the stomach over the perforated ulcer not only as an additional protection, but to prevent adhesions to the fixed tissues around the pancreas.

The principle of physiologic rest in operations upon all ulcers—particularly if perforated—must be borne in mind. In ulcers about the duodenum and pylorus, after occlusion, gastro-enterostomy diverts the current of food from the sutured ulcer and so gives rest. After repair of ulcers in the middle of the stomach the physiologic resistance of the pyloric sphincter must be overcome. Just as it is necessary to divulse the sphincter ani in operations on a rectal ulcer in order to prevent pressure, so it is essential to weaken the grip of the sphincter of the pylorus and the adjacent strong muscles of the pyloric canal by pyloroplasty. This gives rest by enabling the crippled stomach to empty without having to overcome the normal strong physiologic resistance at the pyloric end of the stomach, which may even be accentuated because of the irritation from the operation. By eliminating the necessity for stronger contractions to overcome this physiologic resistance, more rest is induced, and the energies of the tissue can be devoted chiefly to repair.

The treatment of peptic ulcer of the stomach and duodenum depends upon the duration of the ulcer, the size of the ulcer, its location, whether it is a gastric or a duodenal ulcer, and upon the general condition of the patient. Any rule that assumes that peptic ulcers should be treated solely by medical or solely by surgical methods will cause many unfortunate results. Every individual case should be studied and treatment adopted as seems best suited for the case. Medical treatment should always go hand in hand with surgical treatment. It is not a question of medical or surgical treatment, but there should always be a coöperation of medical and surgical treatment. All cases

of peptic ulcer should receive medical treatment either alone or in conjunction with the operation, either before operation, or certainly after operation. The necessity for general treatment of the patient to build up his resistance and to eliminate foci of infection cannot be too greatly emphasized. If an ulcer has only existed a few weeks or a few months and if there is no hemorrhage, medical treatment alone often gives excellent results.

Peptic ulcers of the stomach may undergo malignant transformation and, other things being equal, there is a stronger indication for operating upon ulcers of the stomach than upon ulcers of the duodenum where malignancy resulting from a peptic ulcer is almost unknown. In a large ulcer which has deformed the stomach or duodenum and infiltrated the surrounding tissues and is producing marked symptoms medical treatment may be instituted for at least a few weeks if the ulcer is not of long standing. If, however, there is a distinct ulcer history for a period of a year or more, operation would seem to be indicated without first attempting a cure by medical treatment. The complications that attend ulcers, such as hemorrhage, partial or complete obstruction, and perforation, demand operation.

If it has been determined that operation is the best treatment for a particular peptic ulcer, the type of operation to be done depends upon the nature and the location of the ulcer and frequently cannot be determined until after the abdomen has been opened. The rule of doing a gastro-enterostomy for every gastric or duodenal ulcer has cured many patients, but undoubtedly has also left many uncured, and the proper adaptation of the treatment or the kind of operation best suited to the ulcer would have obtained more beneficial results. Any surgeon who applies blindly one particular operation to all peptic ulcers will secure bad results in many cases, no matter how skillfully he executes his particular technic. The operation must be made to fit the ulcer and not the ulcer the operation. We must bear in mind the principle applicable in all surgery, to remove or correct the pathologic condition and at the same time to restore the normal function of the tissues involved. This principle is nowhere more indicated than in surgery of the stomach and duodenum. When there is a small callous ulcer in the duodenum or stomach without extensive surrounding inflammation the pathologic condition may be removed and at the same time the normal anatomical relations of the tissues of the stomach and the normal gastric physiology restored. On the other hand, when there is an extensive stenosis of the pylorus, when there are many adhesions, or a large infiltrating ulcer of the duodenum exists, restoration to normal is impossible, for the tissues are permanently and extensively damaged. In such cases gastro-enterostomy gives good results.

Gastro-enterostomy with an open pylorus should always be avoided. With pyloric stenosis the alkalinity of the duodenal contents is retained at its maximum and apparently protects the mucosa of the jejunum from the acid gastric juice at the stoma of the gastro-enterostomy. When the pylorus is open, some of the acid gastric juice passes through the pylorus and lowers the alkalinity of the duodenal contents, so lessening the protection of what would otherwise be a highly alkaline duodenal content. It is in cases such as

these with an open pylorus that considerable trouble often develops after gastro-enterostomy; either there is congestion and irritation of the jejunum at the stoma of the gastro-enterostomy or actual ulceration may take place. It seems probable that for every jejunal ulcer that can be demonstrated, there are many instances in which the dumping of the acid gastric contents into the jejunum causes a hyperemia and irritation that will produce symptoms and yet the lesion is not sufficiently advanced to show on roentgenologic examination. Jejunal ulcer is exceedingly rare except after gastro-enterostomy with an open pylorus (Figs. 53, 54).

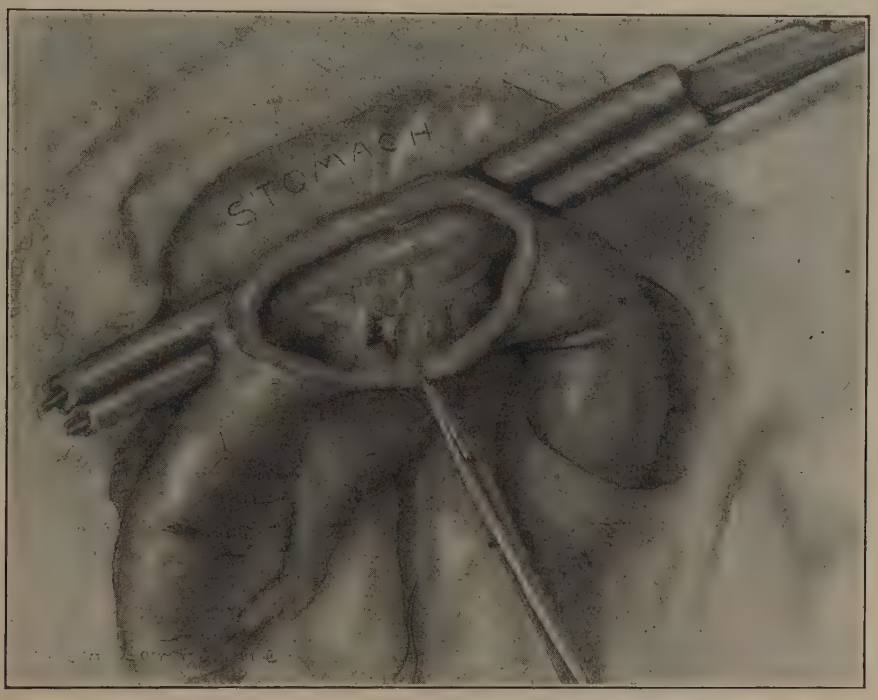


FIG. 53.—A JEJUNAL ULCER AFTER GASTRO-ENTEROSTOMY.
The ulcer in this case is opposite the stoma of the gastro-enterostomy and on the mesenteric border of the jejunum.

Macleod in his work on physiology and biochemistry says: "An important surgical application of these facts [about gastric peristalsis] concerns the behavior of food after gastro-enterostomy. It has been thought that this operation would cause the food to be drained from the stomach into the intestine and thus leave the region of the stomach between the fistula and the pylorus inactive. This assumption is based on the idea, which we have seen to be erroneous, that gravity assists in the emptying of the stomach. As a matter of fact, it has been found that, if the gastro-enterostomy is made when there is no obstruction at the pylorus, the chyme takes its normal passage through the sphincter and, almost without exception, none leaves by the fistula. When the pylorus is partly occluded, the food sometimes passes

in the usual way, and sometimes by the fistula. The cause for this predilection for the pyloric pathway depends on the pressure conditions in the gastric contents. Gastro-enterostomy, therefore, is efficient only when gross mechanical obstruction exists at the pylorus. The operation should never be performed in the absence of demonstrable organic pyloric disease. Another objection to gastro-enterostomy in the presence of a patulous pyloric sphincter rests on the fact that the food, after passing the sphincter and moving along the intestine, may again enter the stomach through the fistula."

According to Davis "gastrojejunal ulcers are secondary to gastro-enterostomies in approximately 8 per cent of all such operations."

Lewisohn has reported a series of gastro-enterostomies from the Mt. Sinai Hospital, New York, the operations being done by the usual accepted technic, with a careful follow-up of the results. He finds in this series that

FIG. 54.—DRAWING OF SEGMENT OF JEJUNUM CONTAINING JEJUNAL ULCER SHOWN IN PREVIOUS ILLUSTRATION.

jejunal ulcers follow gastro-enterostomy in at least 34 per cent of the cases. This percentage is much higher than that reported from other clinics, but as the results in gastric surgery at Mt. Sinai Hospital in other respects seem to be equal to those of the best clinics, it may be assumed that this high percentage is due to the very careful and critical examination of the postoperative course of patients in whom gastro-enterostomy is done. Lewisohn emphasizes that the surgical treatment of jejunal ulcers is one of the most serious problems in gastro-intestinal surgery. They are often accompanied by extensive adhesions to the stomach and large intestine, as well as the adhesions of the omentum to the abdominal wall and to the vessels of the transverse mesocolon. Not infrequently these ulcers perforate.

Lewisohn previously reported that in 18 cases in which he operated by simply excising gastrojejunal and jejunal ulcers, 5 were recurrent gastrojejunal ulcers, and in one case there were two recurrences. The recurrent cases comprised 27 per cent of the total series in which a conservative excision was done.

It is difficult to estimate with any accuracy the exact number of patients who have jejunal ulcers after gastro-enterostomy with an open pylorus. The statistics so far appear to consider all gastro-enterostomies in one group, or, if any division is made, it is merely between those done for benign and those for malignant lesions. Patients with pyloric stenosis or potential stenosis in which the acid gastric juice cannot go through the pylorus to lower the alkalinity of the duodenal contents, almost always do well after a gastro-enterostomy. Formerly, when the roentgenologic diagnosis of peptic ulcer was less accurate than now, operations were chiefly done on advanced ulcer lesions and a large percentage of gastro-enterostomies for ulcer were in patients with complete or potential pyloric stenosis. By potential stenosis is meant a large infiltrating ulcer of the duodenum or pylorus with so much inflammatory reaction as to render it probable that in the healing marked constriction will result. Some of these extensive ulcer lesions, to be sure, heal with comparatively little constriction, but a majority probably result in considerable narrowing of the lumen or a complete stenosis of the pylorus or duodenum.

If, then, this class of cases with stenosis present or potential, which is universally conceded to give good results after gastro-enterostomy, be excluded, and the incidence of jejunal ulcer be calculated in those patients who have a comparatively small ulcer with an open pylorus, we would doubtless find that the percentage of jejunal ulcers would be quite high—naturally much higher than is ordinarily reported after considering the statistics for a group of gastro-enterostomies done indiscriminately on patients with peptic ulcers. If, in addition to this, we assume that there are many cases of congestion or irritation of the mucosa of the jejunum for every demonstrated jejunal ulcer, we can see that the percentage of unsatisfactory results following gastro-enterostomy with an open pylorus would doubtless be very high.

The experimental work of Mann and Williamson, which has been referred to (page 154), seems to bear out this contention, for after diverting the bile and pancreatic juice, which are the chief alkaline constituents of the duodenal contents, they found a typical peptic ulcer would frequently develop in dogs a short distance from the line of union of the intestine and the stomach. The further observation that these ulcers readily heal when this union is disconnected is equally interesting. It seems obvious, then, that all operations are unwise which are designed in such a manner as completely to divert or to dilute the protective influence of the alkaline contents of the duodenum for the jejunal mucosa apposed to the stomach.

The "Y" gastro-enterostomy of Roux, in which the jejunum is divided and the oral end united end-to-side to the jejunum lower down while the distal end is attached to the stomach, involves a violation of this principle. The end of the jejunum implanted on the stomach is unprotected by the alkalinity of the duodenal contents delivered to the jejunum lower down. In patients in whom symptoms do not appear after this operation it seems probable that there may be a reflux of the alkaline contents from the site of

the end-to-side anastomosis, but if this occurs it is merely an incident and not the purpose of the operation.

An operation proposed by Moynihan and others, in which after pyloric resection the distal end of the divided jejunum is sutured to the stomach and the oral end united to the jejunum further down by the end-to-side method, also involves the diversion of the protective alkaline contents and it would seem probable that ulcers should result in the jejunum after such a procedure. An entero-anastomosis in a gastro-enterostomy between two long loops may not divert all of the duodenal contents but doubtless allows some of it to protect the jejunal mucosa opposite the stoma of the gastro-enterostomy opening. This protection, however, by reducing the alkalinity of the duodenal contents delivered at the stoma is obviously diminished.

In the Polya operation of partial gastrectomy, in which a loop of jejunum is attached to the stomach after resection of the pyloric portion of the stomach, it would seem to afford better protection to the apposed jejunun if it be sutured with the oral end of the jejunal loop at the lesser curvature, so that the opening of the jejunum at this point will permit flooding of the attached jejunum with the alkaline duodenal contents delivered at the top of the anastomosis and in the general direction of the peristaltic waves of the jejunum. If the loop of jejunum is applied so that the oral portion is attached to the greater curvature, the duodenal contents will doubtless puddle at the lower portion and will not be distributed equally over the jejunal loop.

If the ulcer is on the pyloric end of the stomach, and particularly if it is large, a pylorectomy is often indicated. After a pylorectomy of this nature the stomach can usually be reconstructed by a modification of the Billroth I operation, which will be described later on. The essential features of the modification of this operation are that the stomach is united to the duodenum along the lesser curvature in the line of the normal peristalsis and the duodenum is split for about one or one and a half inches (2.5 or 3.8 cm.) before the suturing is completed so as to avoid constriction at the line of sutures. If the excision is too extensive to permit the approximation of the stump of the stomach to the duodenum without tension another type of operation should be employed. This is, preferably, Hofmeister's operation or a modification of the Billroth II, in which the upper portion of the gastric stump is closed and the lower portion united to the jejunum after the manner of a posterior gastro-enterostomy. The Polya operation of partial gastrectomy in which a loop of jejunum is united to the entire stump of the stomach through the transverse mesocolon, or the Polya-Balfour method in which the jejunum is brought over the transverse colon and sutured to the stomach, has the disadvantage of a rather long loop of jejunum carried either through the mesocolon or over the transverse colon, with the possibilities of unsatisfactory emptying or of obstruction.

If the ulcer is extensive and involves the middle portion of the lesser curvature of the stomach, a midgastric resection may be done. This apparently gives better results than an extensive V-shaped resection along the lesser curvature. The lesser curvature is the approximate axis of peristalsis and

contains the canalis gastricus. If peristalsis is partially interrupted by a large V-shaped resection along the lesser curvature and the tissues along the lower border of the stomach are left undisturbed, unharmonious peristalsis will result because of interruption along the most important path. It seems better from a physiologic standpoint to remove the whole segment of the stomach if the V-shaped resection must be large, and so place all of the structures on the same basis, and recovery will be more nearly uniform

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# CHAPTER X

## PYLOROPLASTY

There should always be definite indications for the particular operation that is done upon the stomach. If pyloroplasty is used as a routine procedure the results will be fully as unsatisfactory as if gastro-enterostomy is performed in every case of ulcer of the stomach or duodenum. As a rule the less the pathology, the stronger the indication for pyloroplasty.

There may be said to be three different types of pyloroplasty; the Heineke-Mikulicz, the Finney, and the physiologic pyloroplasty which I described about six years ago.

The Heineke-Mikulicz was originally devised to overcome stenosis at the pyloric end of the stomach or in the first portion of the duodenum. The underlying principle of the operation is a plastic procedure in which the constriction is divided by an incision severing the stricture at right angles, and the incision is sutured transversely. This is a well-known principle in plastic surgery, and has been adopted in many instances of visceral stricture. It has no connection whatever with any physiologic function of the tissues involved other than to increase the lumen. The operation was later done in some cases with excision of the ulcer, but the operation was first performed as a plastic procedure for stricture of the pylorus. The originators of the operation seem to have described it somewhat differently from its usual conception. Thus, in Binnie's *Operative Surgery* this operation is so described as to make it resemble Finney's operation. The usual conception of the Heineke-Mikulicz pyloroplasty, and the one which is generally given in the textbooks, is a straight incision with the center over the pyloric stenosis. The ends of the incision terminate in supposedly healthy tissue, one end in the stomach and the other in the duodenum (Fig. 55). After the division the tissues are sutured by two or more layers of sutures. The extremities of the incision should be first united by an interrupted suture so as to fix these two points. The suture had best be absorbable or slowly absorbable material, though Finney, who has had a large experience in pyloroplasty, used silk constantly, at least for the outer layer of sutures, and seems to have had no trouble attributable to silk. As a rule, however, it would probably be safer to avoid the possibility of a low irritation from nonabsorbable sutures in this region, by using tanned or chromic catgut. This kind of catgut holds satisfactorily and will doubtless eventually be absorbed, even if it is not extruded into the lumen of the stomach or duodenum, which is the usual course with nonabsorbable sutures.

In any plastic operation upon the pyloric end of the stomach the work of Dragstedt, already referred to, should be borne in mind. Dragstedt and

Vaughn have shown that an experimental ulcer can be made in the pyloric mucosa of a dog by inserting a number of sutures at one point. The pyloric mucosa, it must be recalled, is peculiarly susceptible to ulcer formation and is that portion of the gastric mucosa whose secretion is alkaline. It seems probable that this latter function is at least one of the important factors which make the mucosa susceptible to ulceration. The pyloric mucosa must be treated with the utmost delicacy and it would be wise not to suture nor even to clamp it. Attention has been called to the fact that wherever in the gastro-intestinal tract the mucosa is sutured it sloughs. Usually the resulting wound heals readily, but in the pyloric mucosa, prone to ulceration, this may be the basis of a chronic peptic ulcer.

The objections to the Heineke-Mikulicz operation as usually described are rather serious. First of all, wherever there is a marked tendency toward stenosis from scar tissue, the stenosis is likely to recur. It seems that the tissues, once having formed the habit of reproducing scar tissue, can hardly be induced to make anything else. Even though the stricture be opened widely in this operation all of the original scar tissue remains. It has merely been divided and in recontraction there is very likely to be a recurrence of the stenosis. Then, too, at the two extremities of the incision after it has been sutured, there is scar tissue, so that at the upper and the lower ends scar tissue must be sutured to scar tissue. As a result of this operation a pouch is formed in a portion of the intestine where the lumen is not normally greatly enlarged, and one half of the pouch consists of stomach and one half of duodenum, tissues that are unequal in thickness and in muscular power. As tissues heal they tend, other things being equal, to contract toward a fixed point. At the pyloric end of the stomach the approximately fixed point is along the upper border of the pylorus and the duodenum. If there is recontraction after healing, the pylorus is lifted high up under the liver so as to make a distinct angulation.

Fig. 55.—The Heineke-Mikulicz Operation as It Is Generally Accepted.

The incision is straight and made with its center at the stenosis.

If the Heineke-Mikulicz operation is used for excision of an ulcer, the fact that a large proportion of this incision is made in tissues that are comparatively fixed and cannot be well mobilized may make the excision of an ulcer somewhat difficult unless it is very small.

The Finney pyloroplasty is a great improvement over the Heineke-Mikulicz type, and may be used satisfactorily in a stenosis where the Heineke-Mikulicz type might fail (Fig. 56). In the Finney pyloroplasty a horseshoe-shaped incision is made with each limb of the incision about 2 inches (5 cm.) or

more in length, and extending from the center at the pylorus down on the anterior surface of the duodenum and on the anterior surface of the stomach approximately along its greater curvature. Before an incision is made the duodenum must be well mobilized by incising the peritoneum along its outer border and sometimes along its inner border. This can be readily done by putting the peritoneum in this region on a stretch after catching the duodenum with forceps and making a nick through the peritoneum with a knife. With spreading scissors dissection the constricting portion of the peritoneum is isolated and divided, or the whole dissection may be made with a knife. The finger can detect any unusual bands and these are also divided. There should be practically no bleeding after such a mobilization, but if there is the vessels will be small and can be readily clamped and tied. It is often unnecessary to incise the peritoneum along the inner border of the duodenum. Here, as elsewhere in gastric and intestinal surgery, there should be no tension on the sutures and if the duodenum cannot be brought over without tension, this operation should not be performed. Such a condition, however, is seldom seen. After mobilizing the tissues some authors suggest the use of intestinal clamps to control bleeding and to prevent soiling of the surrounding tissues by the opening into the stomach and duodenum. Intestinal clamps, however, add an unnecessary trauma and can hardly promote healing. By making the incision in short sections, clamping the bleeding vessels as they are divided, and by withdrawing the contents of the duodenum or stomach with a suction apparatus, there should be no soiling of the surrounding tissues, if sufficiently protected by moist gauze before the stomach and duodenum are opened.

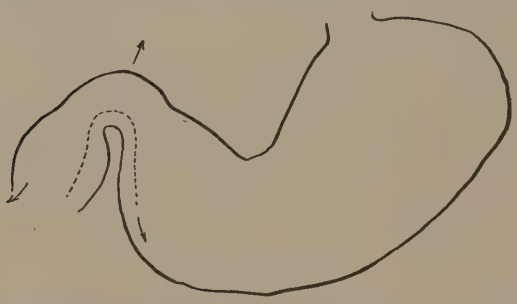

FIG. 56.—DIAGRAM SHOWING THE SITE OF THE INCISION FOR THE FINNEY PYLOROPLASTY.
The incision is represented by the dotted line.

After mobilizing the duodenum and folding it onto the stomach, the duodenum is united to the stomach with a series of sutures (Fig. 57). Finney, in his original technic, used a series of interrupted mattress sutures of silk. He also placed an anterior row of similar silk sutures which were left untied until after the incision was made. Each individual operator can, of course, modify this feature of the technic to suit himself. I use a continuous suture of the mattress type, of 00 tanned catgut as in gastro-enterostomy, taking an occasional backstitch. The duodenum is folded onto the stomach for a distance of about 2 or 2.5 inches (5 or 6.3 cm.). This row of sutures is begun above and temporarily concluded below by taking a backstitch and protecting the needle and thread with a towel until it is used again. An incision is made into the stomach parallel with this row of sutures and about one-third inch (0.9 cm.) from it. The bleeding vessels are clamped with hemostats. The incision is carried through the pylorus and down on

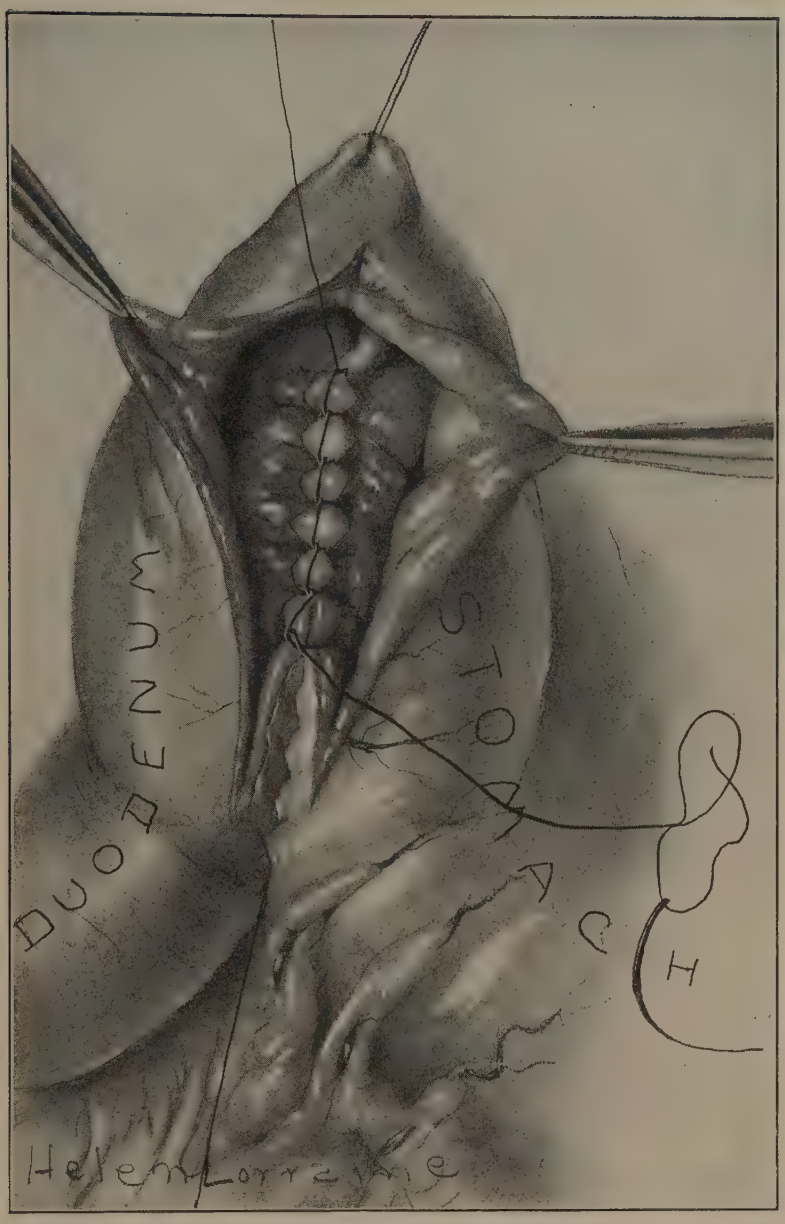


FIG. 57.—AFTER MOBILIZING THE DUODENUM IT IS UNITED TO THE STOMACH WITH A CONTINUOUS ROW OF SUTURES.

Finney uses interrupted mattress sutures. The stomach and duodenum have been incised according to the diagram shown in the preceding figure. The inner row of sutures is being applied.

the duodenum. By making the incision slowly and clamping the vessels as they are divided, and at the same time by evacuating the stomach contents with a suction apparatus, a clear view of the interior of the pylorus and upper duodenum can be obtained. Ulcers along the margin of the wound should be

excised, and posterior ulcers may be either cauterized or excised and sutured, as the occasion demands. If there is anything more than a small superficial ulcer in the posterior wall of the pyloric end of the stomach it would be better to do a pylorectomy than to attempt a resection of the ulcer. The posterior margin of the wound in the stomach is sutured to the posterior margin of the wound in the duodenum with a continuous lockstitch of No. 1 tanned catgut, beginning at the upper end of the wound. This is continued down to the lower extremity of the incision, and then, with the same suture, the anterior margin of the wound in the stomach is united to the anterior margin of the wound in the duodenum with a continuous lockstitch, taking a small bite of tissue in each stitch and being particularly careful to include the bleeding points which have been clamped. Each point that oozes should be whipped over by making an extra backstitch at this point. The suture ends at the pylorus anteriorly and is tied several times. This inner row of sutures is buried by continuing the original row of 00 tanned catgut which had been placed posteriorly and temporarily discontinued. It is carried forward and upward as a right-angle continuous suture, taking a backstitch at intervals. If there are any doubtful points an additional suture of 00 tanned catgut may be applied, and as an abundance of precaution a tag of adjacent gastrocolic omentum, or even of great omentum, may be brought over the line of sutures and fixed by a few interrupted sutures.

The advantages of this pyloroplasty are those of pyloroplasty in general; it conforms more nearly to the physiology of the stomach than gastroenterostomy would. It also has a distinct advantage over the Heineke-Mikulicz type of operation in that the lumen cannot be impaired by recontraction of the stenosis. It is essentially gastroduodenostomy, and even if the stenosis could recur there would still be ample opening external to the pyloric sphincter through the incisions in the stomach and the duodenum.

Finney has reported that subsequent roentgenologic observations show that even after such an extensive division there is still in many cases some sphincteric action in the pyloric portion of the stomach.

The disadvantages of the operation are that the mobilization of the duodenum is sometimes a little difficult and that when the ulcer is extensive suturing infiltrated tissue is not always either safe or ultimately satisfactory. Finney reports a very few recurrences of the ulcer. The gastric drainage feature which has been emphasized as one of the advantages of this operation is probably of not so much importance as is the division of the pyloric portion of the stomach in which spasm usually resides, thereby lessening the physiologic resistance. The length of the incision and the amount of suturing, while not great, constitute a slight objection. Then, too, if the operation is done for stenosis, the same objection of suturing scar tissue to scar tissue holds as in the Heineke-Mikulicz pyloroplasty.

The type of pyloroplasty which I have termed a physiologic pyloroplasty seems to have a definite field. This operation was described in 1919. Since that time the operation has been modified in some rather important features, though the principle of it remains the same, which is to excise the ulcer

and so eliminate the pathologic lesion and to give rest to the pyloric end of the stomach by dividing the active muscular portion of the pylorus consisting chiefly of the pyloric sphincter and canal. The incision is never carried farther than an inch (2½ cm.) into the duodenum, and should always be at least twice as long in the stomach as in the duodenum. The pyloric canal is about 1¼ inches (3 cm.) long, and this at least should always be divided.

In a general way it may be said that the less the local pathology the stronger is the indication for this pyloroplasty. In extensive adhesions, where there is a marked stenosis or when the ulcer in the duodenum has infiltrated the tissues for one-third or more of the circumference of the duodenum, this pyloroplasty should not be done If there are extensive adhesions around the duodenum this pyloroplasty is not indicated. If the adhesions are merely to the gall-bladder, however, the pyloroplasty may be done and the gall-bladder removed, because it seems probable that a cholecystitis was initiated at the same time that the ulcer arose, and the adhesions about the gall-bladder are an expression of a previous cholecystitis which has doubtless become latent. As I have found in the earlier series of these cases when the adhesions to the gall-bladder were merely divided and the gall-bladder left, the manipulation would often stir up the latent infection in the gall-bladder and the subsequent adhesions would be greater than the first. Adhesions about the first portion of the duodenum or the pyloric end of the stomach are the bane of a pyloroplasty. Adhesions in a portion of the gastro-intestinal tract, such as the jejunum, ileum, or transverse colon, where there is normally a wide excursion of movement, are not very important unless they cause an actual obstruction, because the intestine with such free range of motion can adapt itself to adhesions without particular complaint, and without any unusual burden upon its muscular coats. When, however, adhesions occur in a part of the gastro-intestinal tract that is comparatively fixed, as in the pylorus, in the upper portion of the duodenum and around the ileocecal valve or the terminal sigmoid, symptoms may arise for the reason that the already limited excursions of such a portion of the gastro-intestinal channel are further restricted and this throws undue strain upon the muscular elements in an effort at normal peristalsis. In much the same way adhesion of the heart to the chest wall renders it necessary for every muscular action of the whole organ to approximate toward the fixed adherent point in addition to doing the work that is necessary for emptying itself. If, then, the adhesions around the first portion of the duodenum and the pyloric portion of the stomach extend well beyond the region of the gall-bladder, it is needless to attempt a pyloroplasty even of the Finney type, which would stand more adhesions without giving symptoms than would the pyloroplasty of the physiologic type.

In the presence of a marked stenosis the tendency toward recurrence makes a distinct contraindication for this pyloroplasty. If, however, there is a narrow band of contraction without much inflammatory reaction and without surrounding adhesions, this physiologic pyloroplasty would doubtless be satisfactory, because the limited amount of connective tissue and the absence of

reaction would render a recurrence of the stenosis improbable. In V-shaped excision of an ulcer of the stomach this pyloroplasty is particularly indicated, and also when there is a limited duodenal ulcer confined to the first inch of the duodenum with little or no surrounding infiltration. These indications, then—a limited small duodenal ulcer in the first portion of the duodenum or a small ulcer in the anterior wall of the pyloric portion of the stomach, a V-shaped excision of an ulcer elsewhere in the stomach, or a very narrow stenosis—comprise the indications for this pyloroplasty. This field, though seemingly narrow, covers a considerable percentage of ulcers of the stomach and duodenum. In my own experience it is about 40 per cent.

In a "sleeve" resection the motor function of the stomach is not so much interfered with as when there is a large V-shaped resection along the lesser curvature, because all of the peristaltic impulses have been equally interrupted in a "sleeve" resection, whereas only a portion of them have been abolished in a V-shaped resection and the resulting peristalsis has been rendered inharmonious. There is, therefore, an indication for a physiologic pyloroplasty to overcome the normal obstruction afforded by the pylorus. Heretofore it has been customary to do a gastro-enterostomy in this type of case. Gastro-enterostomy seems to be inappropriate here, because jejunal ulcers are prone to occur after gastro-enterostomy when there is an open pylorus; so, after comparative rest has been afforded the stomach by gastro-enterostomy and the gastric wound has healed, a condition is left which is not only unphysiologic but predisposes very markedly to a jejunal ulcer—a lesion more difficult to treat either surgically or medically than the original gastric ulcer. The necessity for some form of rest of the stomach, however, is obvious. This is because after excision of the gastric ulcer the trauma to the stomach impairs its motility and renders it more difficult for the stomach to empty. The normal physiologic resistance to the pylorus is doubtless heightened by the irritation from the operation on the stomach. In other words, the condition is somewhat similar to operation upon an ulcer of the rectum, where the irritation from the ulcer has produced a spastic sphincter ani. If the ulcer is excised and the power of the sphincter ani is left intact, the accumulated gas and fecal matter in the rectum will require more muscular power than normal to be expelled through the spastic sphincter ani. If the sphincter ani is divided or divulsed, not only is this additional spasm done away with, but the normal physiologic resistance of the sphincter ani has been overcome and the muscular structures of the rectum and sigmoid are given a comparative rest because of removal of even the normal physiologic resistance of the sphincter. To carry this analogy back to the stomach, the emptying of the stomach, the function of whose musculature has been impaired by an operation, can be greatly facilitated by removing the normal physiologic resistance of the powerful muscles of the pyloric sphincter and the pyloric canal. This is best done by the physiologic pyloroplasty.

The main purposes of this pyloroplasty, then, are to remove or to correct pathologic conditions, to give physiologic rest during healing, and to restore the tissues eventually as nearly as possible to their physiologic normal. When

tissues are too much damaged for restoration, of course such an operation is not indicated.

The proper operation for any case cannot always be definitely determined until the abdomen has been opened. The first step is a satisfactory exposure. This is best made by a rather long incision beginning just below the ensiform cartilage and continuing downward and slightly onward along the inner portion of the right rectus muscle to about the level of the navel. If the muscles are unusually thick or if there is considerable fat, the lower end of the incision may be directed obliquely outward through the rectus muscle as in the Bevan incision, but ordinarily this does not seem to be necessary. If the pyloroplasty is to be secondary to the resection of an ulcer in the

Fig. 58.—The Incision for the Physiologic Pyloroplasty.

The incision should never extend more than an inch into the duodenum, and the gastric portion of the incision should be at least twice as long as the incision into the duodenum. The ulcer is excised wherever possible.

stomach, this latter operation must be performed first, and after it has been completed the pyloroplasty is done. After the pathologic conditions have been ascertained, and if the physiologic pyloroplasty seems to be the suitable operation, the pyloric portion of the stomach is packed around with moist gauze. When the pathology is located at the pyloric portion of the stomach or in the first part of the duodenum, the pylorus is brought into the wound as much as possible. If there are pyloric adhesions or attachments of the duodenum which prevent normal mobilization of the pyloric end of the stomach and the first part of the duodenum, it is doubtful whether this type of pyloroplasty should be done.

A point is selected on the anterior surface of the pyloric portion of the stomach midway between the greater and lesser curvatures and about 2 inches (5 cm.) from the pylorus (Fig. 58). This is fixed by Allis forceps. If

the lesion is in the anterior part of the duodenum, as it usually is, and if it requires an incision of about an inch (2.5 cm.) into the duodenum, the incision into the stomach should be at least twice the incision into the duodenum, the ratio being always at least two to one. This can be determined roughly before the incision is made in the stomach. If the lesion is at the pylorus so that the incision into the duodenum need be only a half inch (1.3 cm.), an opening an inch or an inch and a half (2.5 or 3.8 cm.) long into the stomach is all that is necessary. It is best, however, never to make the incision into the stomach less than 1¼ inches (3.2 cm.), for otherwise all of

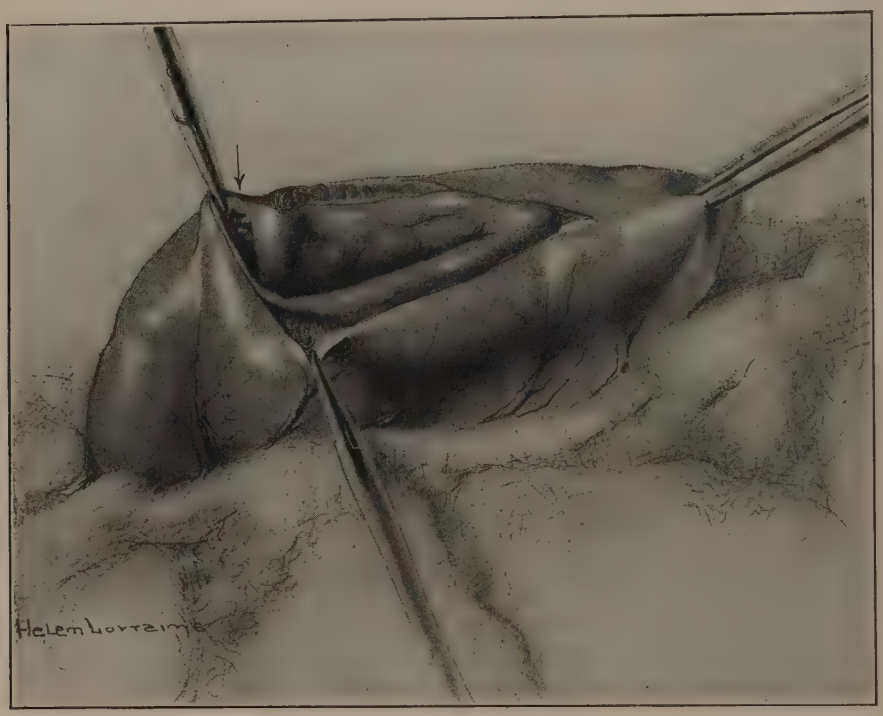

FIG. 59.—THE INCISION HAS BEEN MADE THROUGH THE PYLORIC SPHINCTER AND THE ULCER IS EXPOSED

The next step in the operation should be the excision of the ulcer.

the powerful muscle around the pyloric canal will not be divided. If it has been determined that the incision shall extend about an inch (2.5 cm.) into the duodenum, a cut is made into the pyloric portion of the stomach from a fixed point 2 inches (5 cm.) from the pylorus to the pyloric sphincter. One of the most important features about this pyloroplasty is that the incision must never be more than an inch (2.5 cm.) into the duodenum and always at least twice as long in the stomach as in the duodenum. If this is not done the chief principle upon which the operation is founded will be neglected, for the sutured incision should begin and end in the stomach wall and the strong musculature of the pyloric end of the stomach must be divided. If the lesion is so situated that an incision along these lines cannot be made, this pyloro-

plasty should not be done. It is best not to divide the gastric mucosa at the first incision, so that the bleeding vessels which are usually small in this region may be clamped with small sharp hemostats.

After the bleeding has been controlled, the gastric mucosa which bulges into the wound is incised and the tip of a suction apparatus introduced to draw off the gas or fluid. The incision is carried to the pyloric sphincter, which is carefully divided and the ulcer in the duodenum is exposed. In this manner the ulcer may be inspected before any traction or trauma on the tissue has injured it (Fig. 59). Frequently the duodenal tissues tear easily and the mucosa may be readily abraided by rough sponging. It is best not to use a sponge on the duodenal mucosa unless necessary, and then have the sponge wet in salt solution and applied as a mop, not wiping the surface.

FIG. 60.—A TRACTOR SUTURE IS APPLIED FROM THE EXTREMITY OF THE WOUND IN THE STOMACH TO THE EXTREMITY OF THE WOUND IN THE DUODENUM.

On the gastric end of the incision the suture includes the peritoneal and muscular coats but not the mucosa, while it penetrates the entire wall of the duodenum.

The ulcer of the duodenum being exposed, it is excised with scissors together with a small surrounding area of apparently healthy duodenal mucosa. The vessels that bleed after excision of the duodenal wall containing the ulcer are clamped with small hemostats and the duodenal contents drawn off at intervals with the suction apparatus. This incision gives a good view of the pyloric portion of the stomach, the pylorus itself and the first portion of the duodenum. These tissues should be carefully inspected. Suspicious points may be cleared by a very gentle mopping with a sponge wet with salt solution. As secretions from the stomach and duodenum arise, they are removed with a suction apparatus which should be applied gently. It should be definitely determined whether there is an ulcer posteriorly or any other pathology than an obvious anterior ulcer. If there is a marked ulcer in the posterior portion

of the pylorus, a pylorectomy should be done, and not a pyloroplasty. An ulcer that is infiltrating in the posterior wall of the first part of the duodenum may be cauterized or excised, but probably the best treatment is to ligate the pylorus and so give rest to the tissues and do a posterior gastro-enterostomy.

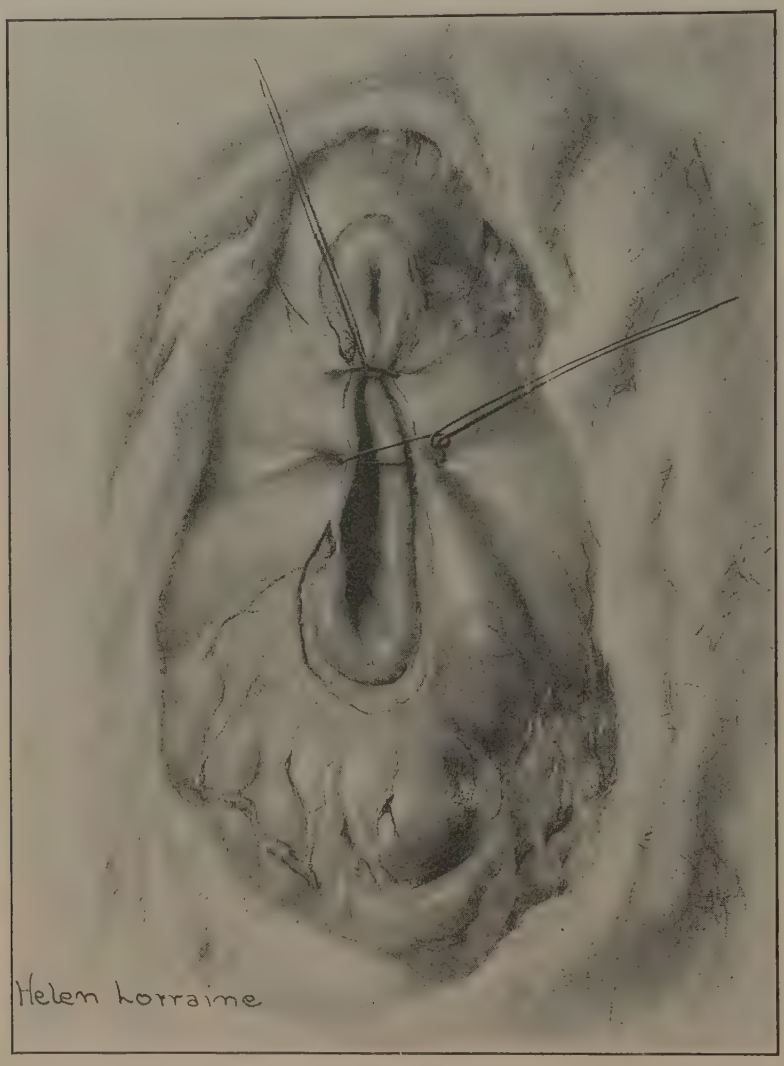


FIG. 61.—THE TWO TRACTOR SUTURES HAVE BEEN APPLIED, THE SECOND ABOUT A HALF-INCH ABOVE THE FIRST.
They are tied gently and convert a longitudinal into a transverse wound.

A tractor suture of No. 1 tanned catgut is placed from the extremity of the wound in the stomach to the extremity of the wound in the duodenum. This suture is inserted in the stomach so as to embrace the peritoneal and muscular coats, but not the mucosa, but it penetrates the entire duodenal wall (Fig. 60). In clamping the bleeding points great care should be taken to

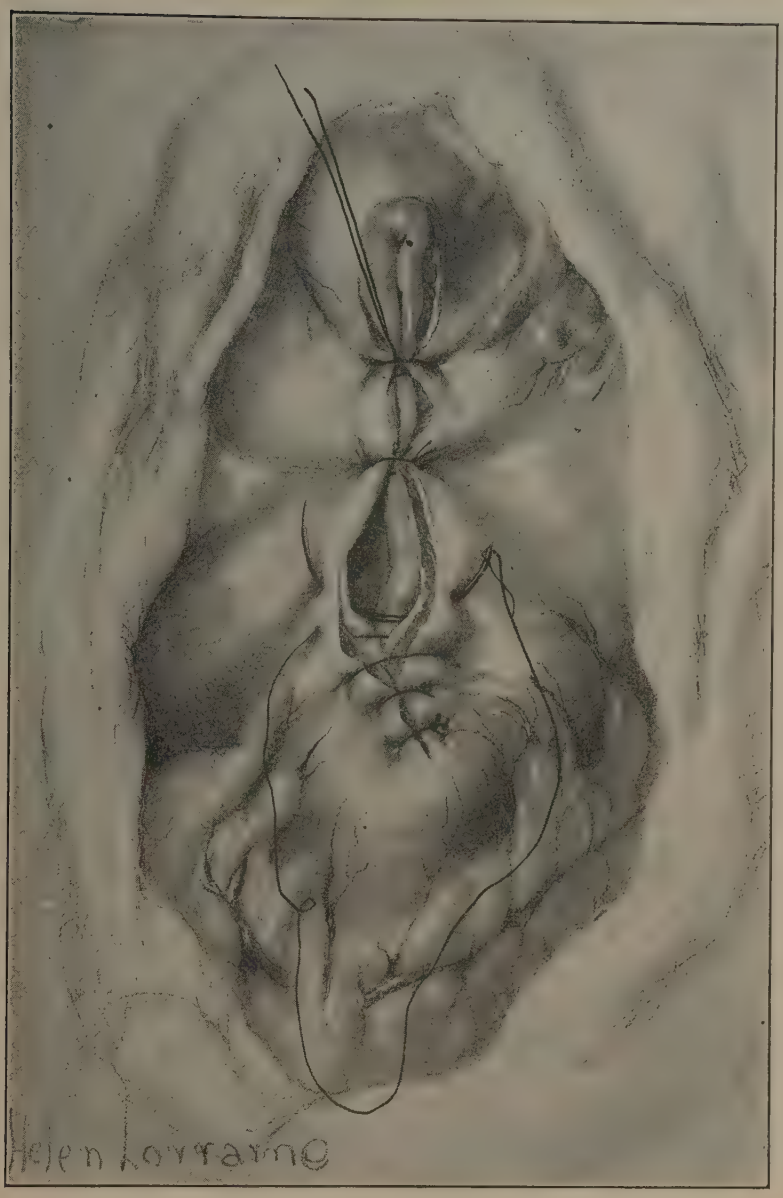


FIG. 62.—THE INNER ROW OF SUTURES IS BEING APPLIED.

It includes only the peritoneal and muscular coats of the stomach, taking particular care to avoid the pyloric mucosa, but the whole wall of the duodenum is caught in the stitch. This brings a curtain of untraumatized gastric mucosa over the sutured duodenal mucosa, which probably acts as a protection against recurrent ulcer.

catch the vessels as they appear in the submucosa and not to clamp the pyloric mucosa if it can be avoided. A second tractor suture is similarly placed a half inch (1.3 cm.) above the first, going through the peritoneal and muscular coats only in the stomach, but taking the whole thickness of the duodenal wall. The duodenum itself is so friable that it is not practical to

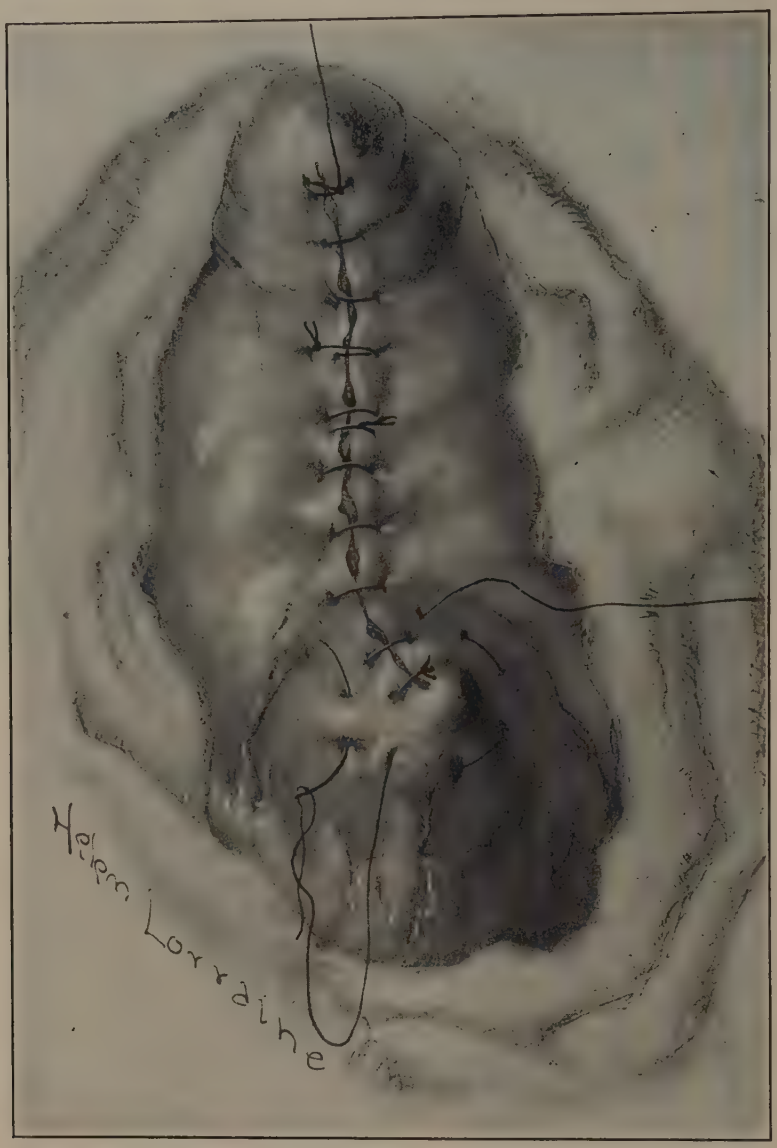

FIG. 63.—THE FIRST ROW OF SUTURES HAS BEEN COMPLETED AS DESCRIBED IN THE PRECEDING FIGURE.

The tissue is brought together sufficiently snugly to control bleeding, which avoids the necessity of ligating individual bleeding points. No effort is made to invert the tissue in this inner row of sutures. The outer row begins as a purse-string suture at the lower extremity of the incision, invaginating the teat at this point.

secure a satisfactory hold upon it if the muscular layer is separated from the mucosa. In addition to this point, there does not appear to be evidence that duodenal ulcers are so readily caused by trauma of the duodenal mucosa as are gastric ulcers from trauma of the pyloric mucosa. These two tractor sutures are lightly tied. If tied tightly they may cut through the duodenal

insertion. They are held up gently so as to lift the anterior wall of the pylorus from its posterior wall. These sutures convert a longitudinal incision into a transverse wound (Fig. 61).

This wound is then sutured with a continuous suture of No. 1 tanned catgut in a round needle. Here, too, care is taken to avoid injury to the pyloric mucosa which should not be even grasped with forceps if it can be avoided. The suture, beginning at the lower end of the wound, approximates the peritoneal and muscular coats of the stomach on one side to the peritoneal and muscular coats on the apposing side. After the pyloric sphincter has been reached the suture includes the whole thickness of the duodenal wall on the right while still including only the gastric peritoneal and muscular coats on the left. The suture is a continuous suture, making no effort to invert tissue but approximating the margins of the wound snugly (Fig. 62). As the hemostats on the bleeding vessels are reached, they are removed. The suture is placed in such a way as to control these bleeding points, and if for any reason each of these points is not controlled a backstitch is taken until all bleeding ceases. When the upper end of the divided pyloric sphincter is reached the suture is placed as in the beginning, uniting the muscular and peritoneal coats of the stomach on one side to those on the other side. When this suture is terminated the bleeding should be completely controlled. If any oozing point is found it should be whipped over with a suture, though this should have been checked by the continuous suture as it was applied. The flap of pyloric mucosa opposite the duodenal wall hangs over as a curtain and doubtless protects the margin of the duodenal mucosa, at least for a while, and in this way may prevent any bad effects from the suturing of the duodenal mucosa.

A second row of sutures of 00 tanned catgut is applied, beginning at the lower angle of the wound. The first row makes a decided teat at the lower angle, and a moderate teat of tissue at the upper angle. The lower teat is buried by beginning this second row of sutures as a purse-string suture and invaginating the teat as the suture is tied. As the pyloric mucosa is in folds, or rugæ, and is redundant, this invagination probably does not prevent the raw surface of the sutured wound at this point from being protected by the redundant mucosa (Fig. 63).

After this invagination the suture is continued as a right-angle continuous stitch, burying the first row of sutures and taking a backstitch at intervals of every 3 or 4 sutures, thus locking the suture (Fig. 64). After reaching the upper teat the row of sutures is again converted into a purse-string suture and the upper teat is buried. Often there is a tag of gastrohepatic omentum hanging down from above. This is caught and fastened over the upper portion of the line of suture with a single interrupted stitch of 00 tanned catgut. A tag of gastrocolic omentum is brought up from the lower portion of the wound and fastened over the lower two-thirds of the suture line with a few interrupted sutures of 00 tanned catgut placed over the suture line, on the stomach, and on the duodenum. In this way the tag is spread out over the line of sutures and strengthens it (Fig. 65). It also tends to prevent adhesions

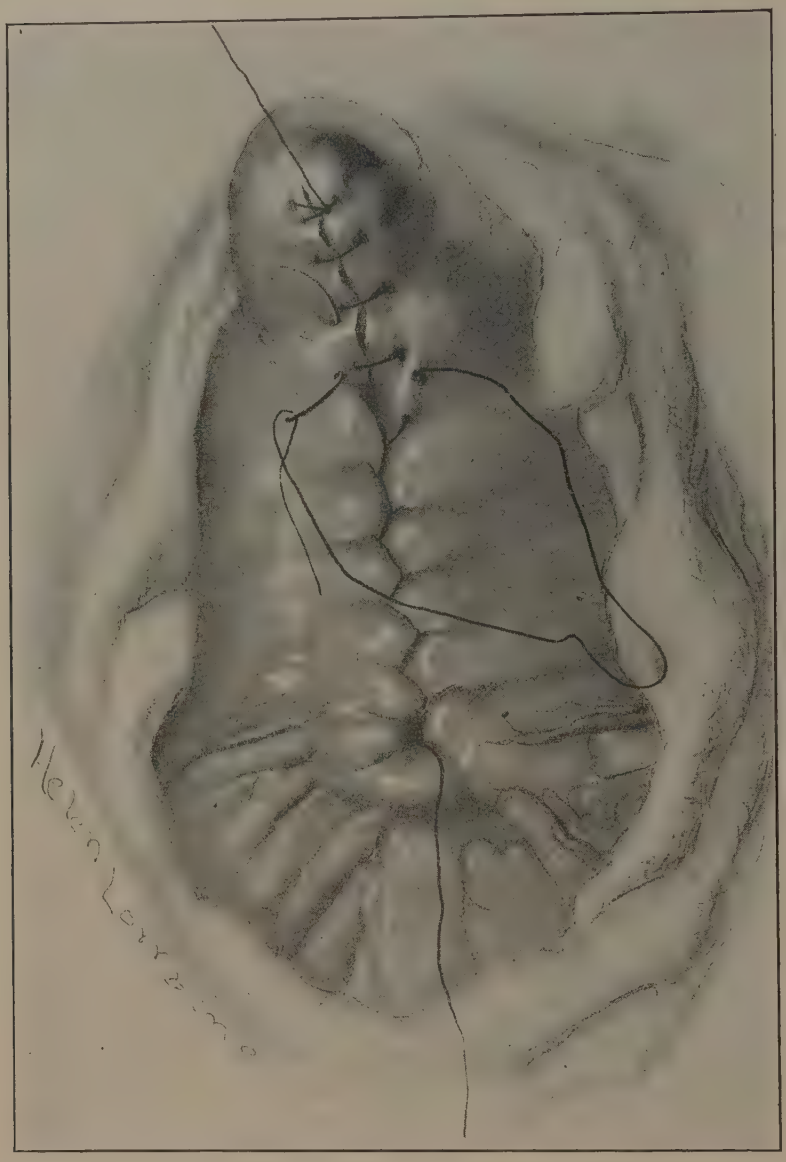

FIG. 64.—THE OUTER ROW OF SUTURES IS CONTINUED AS A RIGHT-ANGLE CONTINUOUS SUTURE, WITH AN OCCASIONAL BACKSTITCH, APPROXIMATING THE PERITONEUM AND BURYING THE INNER ROW OF SUTURES.

When the upper teat is reached a backstitch is taken and the upper teat is buried by terminating this row of sutures as a purse-string suture in the same manner as it began.

to the surrounding tissues. Another advantage is that when the patient is in the erect position the traction of this tag downward doubtless prevents contraction of the suture line toward the liver, as often occurs in the Heineke-Mikulicz type of pyloroplasty. This contraction, however, would not be quite so liable to occur in this physiologic pyloroplasty as in the Heineke-Mikulicz,

because the upper end of the row of sutures is toward the stomach side which is not so firmly fixed as with the Heineke-Mikulicz operation where it is opposite the pyloric sphincter or the divided stenosis.

If there are adhesions about the gall-bladder, the gall-bladder should be removed at the time of the pyloroplasty. In the earlier cases the adhesions were merely separated and the gall-bladder, if it was not obviously diseased,

FIG. 65.—AFTER THE OUTER ROW OF SUTURES HAS BEEN COMPLETED, TAGS OF GASTROCOLIC AND OF GASTROHEPATIC OMENTUM ARE BROUGHT OVER THE SUTURE LINE AND FASTENED WITH A FEW INTERRUPTED SUTURES OF 00 TANNED CATGUT.

was not removed. This was a mistake, because in some of these cases there was a recurrence of symptoms and after removal of the gall-bladder the symptoms were usually relieved. These symptoms are doubtless caused by the adhesions to the duodenum and pylorus which are comparatively fixed, and resent any further limitation upon a normally limited range of motion. This has already been discussed. If the gall-bladder is removed the technic should be one in which drainage to the stump of the cystic duct is not employed, for the drainage tube in itself is a great promoter of

adhesions. The technic I use for removal of the gall-bladder, which is always done in performing a pyloroplasty if there are the slightest adhesions, is, after isolating, doubly clamping, and dividing the cystic duct, removal of the gall-bladder from below upward. The raw surface left on the liver is whipped over with plain catgut. The cystic duct is tied with two ligatures of No. 1 tanned catgut about one-eighth inch (0.3 cm.) apart. The ends of the last ligature are left long, and one end is threaded in a needle and passed through the outer margin of the tag of gastrocolic omentum that was fastened over the line of sutures of the pyloroplasty. The ligature is tied, bringing the omentum snugly to the stump of the cystic duct. If this tag is not ample the right margin of the great omentum is utilized. This is an important point in the technic because the peritoneal covered fat applied snugly to the stump of the cystic duct not only prevents adhesions but acts as a plug and makes more secure the healing of the cystic duct, so that leakage of bile is not likely to occur. If the cystic duct is left unprotected, even with a double ligature, there is a tendency for dilatation and possibly for leakage.

The advantages of this pyloroplasty have been discussed while it was being described, and emphasis has been placed upon the definite field in which it should be applied. That such a field does exist, however, is increasingly obvious as many of the strongest advocates of gastro-enterostomy admit. Thus, so distinguished a surgeon as C. H. Mayo, in a letter to me under date of June 25, 1924, writes as follows: "At the present time in nearly forty per cent of our cases of ulcers of the duodenum we are trying to confine the work to the pylorus and region of the ulcer instead of making a gastro-enterostomy." This is about the proportion of cases in which I employ a pyloroplasty.

In the first 12 of these pyloroplasties in my series of 66 cases there were 3 deaths. All of these deaths could probably be avoided now. In the first death there was an ulcer in the posterior wall of the stomach near the lesser curvature. A transgastric incision was made and the ulcer was excised from within. There was considerable bleeding and intragastric mattress sutures of tanned catgut were applied not only to approximate the tissue but to control bleeding. This pyloroplasty was then done. The patient made a satisfactory immediate recovery, but about the nineteenth day had a very severe hemorrhage from the stomach. This was repeated on the following day, and in spite of gastric lavage and transfusion of blood the patient died. Postmortem examination showed the wound of the pyloroplasty to be in excellent condition. The pylorus was wide. The sutures in the gastric ulcer, however, had been tied too tightly, and caused necrosis, so that the ulcer extended toward the lesser curvature and involved a large vessel from which the hemorrhage came. The second death was in a patient in whom this pyloroplasty was done for stenosis of the pylorus. The stricture was not very dense, but was doubtless so thick that it would hardly have been now considered a proper field for pyloroplasty. After making the incision for the pyloroplasty, the posterior constricting band was divided. The incision was carried too deeply and there was a moderate amount of bleeding. This was

controlled by whipping over the tissues with tanned catgut. The patient made an immediate satisfactory recovery, but had a gastric hemorrhage on the eighth day. An effort was made to control the bleeding by washing the stomach and by transfusion, but this patient, too, died. Postmortem examina-

Fig. 66.—Roentgenogram Showing a Defect Made by a Gastric Ulcer near the Pyloric End of the Stomach.

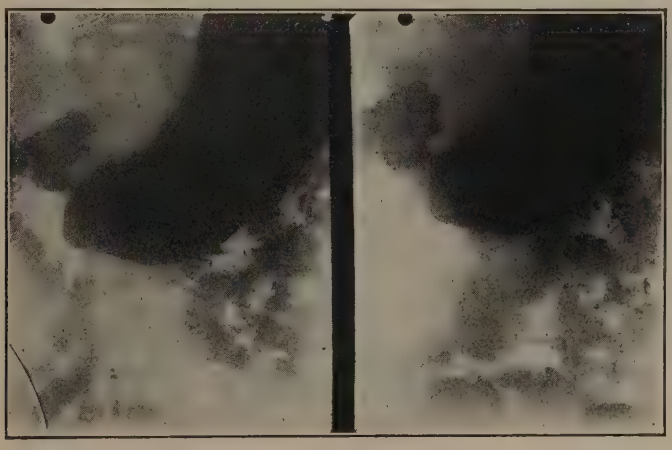

Fig. 67.—Roentgenogram Showing Result Five Years and Nine Months after Physiologic Pyloroplasty on the Stomach in the Preceding Figure.

These two exposures were a few seconds apart. The stomach appears to be functioning normally, and the patient is symptom-free.

tion showed the tissues were in good condition, but the catgut used to suture over the bleeding surface of the divided stricture had been absorbed and the hemorrhage was from this region. The third death was in the twelfth case of this series, in a patient in whom the kidney function had not been sufficiently studied. The patient died of uremia two days after operation. Necropsy showed the wound in good shape, and there was no bleeding.

Since the twelfth case I have done 54 pyloroplasties without a death. In a paper read before the Section on Obstetrics, Gynecology and Abdominal Surgery of the American Medical Association in June, 1923, the results of 56 of these pyloroplasties that I had done up to that time were published. The 3 deaths in the first 12 cases were discussed. All but 2 of the patients had been traced. Thirty-two were complaint-free, 14 improved, 5 were unimproved and required a second operation as gastro-enterostomy or pylorectomy, but are now complaint-free. At that time 3 patients had been demonstrated by secondary operation to have a recurrent ulcer. Since then there have been 6 additional cases of recurrent ulcer, 5 of which were demonstrated by operation and the fourth by careful roentgenoscopic examination by Fred M. Hodges. This patient was given medical treatment and is now almost complaint-free. These recurrences are usually along the suture line. Three of these recurrent ulcers were in patients reported in 1923 as improved, though it was not known then that there was another ulcer, and 3 in patients reported then as complaint-free. Since the report of 1923 I have done 10 additional pyloroplasties without mortality, making a total number of 66 cases, all deaths being in the first 12.

The sole serious objection to this operation when done for the indications that have been outlined is the number of recurrent ulcers. Failures when this pyloroplasty is done in improper cases should not be counted against the technic. It must be recalled, however, that the pyloric portion of the stomach and the first part of the duodenum are peculiarly prone to ulceration, and even if the recurrent ulcers in this region equalled jejunal ulcers following gastro-enterostomies with an open pylorus, the conditions are very dissimilar, because there is almost never a jejunal ulcer without a gastro-enterostomy, whereas a pyloric or duodenal ulcer is prone to occur without operation.

In studying these recurrent ulcers they always appear along the line of sutures or in the gastric side. The work of Dragstedt which has already been referred to is important in this connection. In the original technic two tractor sutures were placed through the whole wall of the stomach, including the mucosa. Then the mucosa was sutured, and finally two other rows of sutures were placed. It can be readily seen that in this handling and suturing of the pyloric mucosa, where the conditions are ideal for producing ulcer, a recurrence is most probable.

Since May 1, 1924, the original technic has been modified to the present technic described, omitting the inner row of sutures and taking care not to suture the pyloric mucosa or clamp it with forceps. While the pyloroplasties done since that time are too few to determine the effect of this change, it seems that it should greatly reduce the number of recurrent ulcers, and no evidence of a recurrent ulcer in these cases has so far appeared. As these patients are mostly from regions that are accessible to Richmond, they have been carefully watched and encouraged to report any unusual symptoms. I believe that in this way no serious complication or complaint has been overlooked, but even if the incidence of recurrent ulcers could not be reduced below what it appears to be in the series of cases ending May 1, 1924, the condition

would be better than if a gastro-enterostomy had been performed with an open pylorus. The incidence of jejunal ulcer in such instances is very high. According to the report of R. Lewisohn already mentioned, more than 34 per cent of jejunal ulcers follow all gastro-enterostomies at Mt. Sinai Hospital in New York. An operation for the relief of jejunal ulcer is more difficult

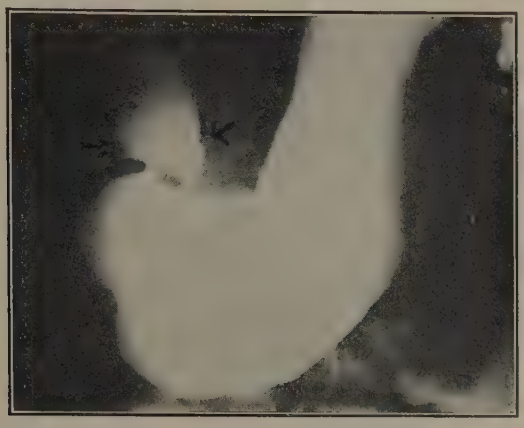

Fig. 68.—Roentgenogram Showing Filling Defect Due to Duodenal Ulcer.

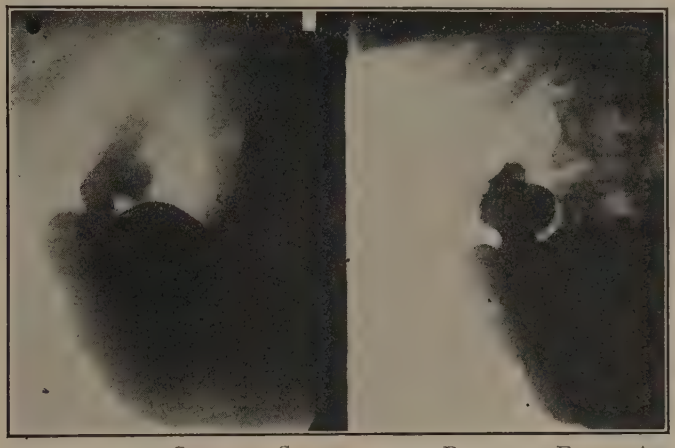

Fig. 69.—Roentgenograms of Stomach Shown in the Preceding Figure About Six Years after Physiologic Pyloroplasty.

The exposures were a few seconds apart. The stomach is apparently functioning normally. The patient is symptom-free.

and dangerous than an operation for a recurrent ulcer after pyloroplasty—which would probably consist of a closure of the pylorus by a stout kangaroo tendon and a posterior gastro-enterostomy. If there is a marked tendency to recurrence of the ulcer, a pylorectomy should be done, but usually an occlusion of the pylorus along with a posterior gastro-enterostomy, as has been indicated, is all that is necessary.

In following these cases an effort has been made to bring out any real divergence from what is considered the normal function of the stomach

in order properly to evaluate the effect of the operative procedure. The results are not considered satisfactory when there is a rather constant belching of gas or regurgitation, or occasional vomiting, or if soda or food between meals has to be used by the patient in order to be comfortable. Even patients who are physically in good condition and able to attend to their work with occasional recurrent symptoms are not considered to have had satisfactory results.

The technical advantages of this pyloroplasty in properly selected cases are that it is easy to perform and that it gives a wide view of the pyloric end of the stomach and the adjacent duodenum. The muscular action of the pylorus and the pyloric canal is greatly diminished during healing, so the affected tissue has comparative physiologic rest, while at the same time the caliber

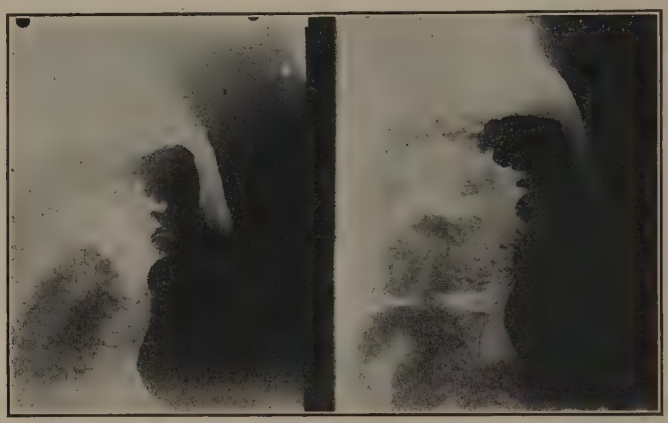

FIG. 70.—ROENTGENOGRAMS OF STOMACH A YEAR AND TEN MONTHS AFTER PYLOROPLASTY FOR DUODENAL ULCER.

The stomach is apparently functioning normally and the patient is symptom-free. There are defects due to the invagination and suturing, though there is no spasm and no tenderness. In these cases (Figs. 67, 69, and 70) the pyloric sphincter is somewhat wider than normal and the stomach empties within about four hours. The function in all is practically normal except that the emptying time is a little faster than normal.

of the pyloric sphincter and the pyloric canal is enlarged without destroying their function. The incision placed as it is makes the sutured wound begin and end in the healthy stomach tissue, and does not materially alter the normal axis for the peristaltic waves of the stomach, which is chiefly along the lesser curvature. In other words, it appears to enable the pathology in these cases to be definitely removed or be corrected, and at the same time it restores normal physiologic function while rendering the pyloric sphincter and the pyloric portion of the stomach unable to become markedly spastic (Figs. 66-70).

## COMPLICATIONS AND SEQUELÆ OF PYLOROPLASTY

The chief immediate complication of pyloroplasty, particularly of the physiologic pyloroplasty, is the inability of the stomach satisfactorily to empty

during the first few days after operation. This is by no means present in all cases, and is doubtless not so severe in the Finney type of pyloroplasty, where the opening is wide, as in the physiologic type of pyloroplasty. Any trauma, however, to the outlet of the stomach when it is essential for the food to pass

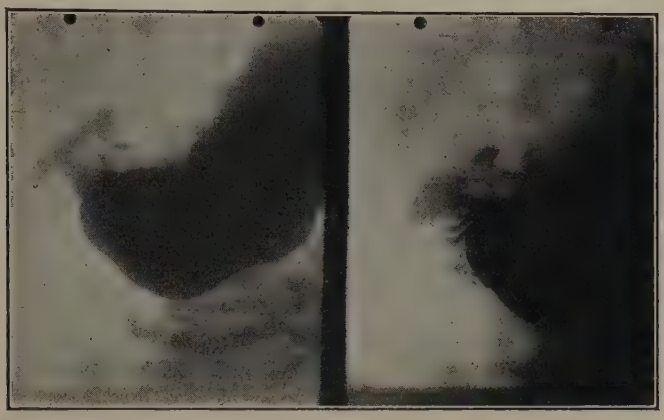

FIG. 71.—ROENTGENOGRAMS OF RECURRENT ULCER AFTER PYLOROPLASTY.
The exposures were a few seconds apart. There was slight retention for a pyloroplasty, the stomach emptying in six hours. There was also hyperperistalsis. At subsequent operation a recurrent ulcer near the suture line was demonstrated.

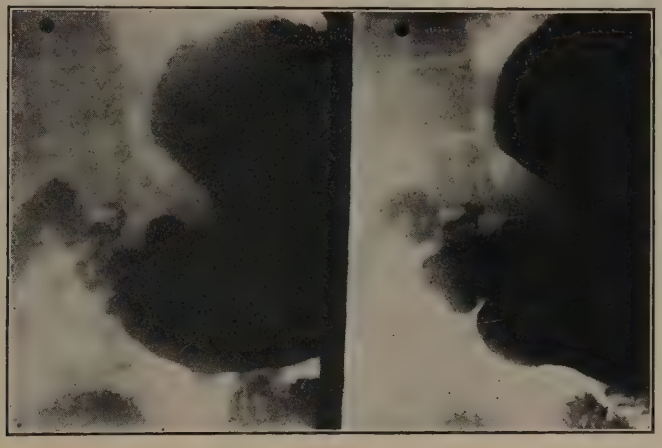

FIG. 72.—ROENTGENOGRAMS OF WHAT APPEARS TO BE RECURRENT ULCER AFTER PYLOROPLASTY.
The exposures were a few seconds apart. Roentgenologic report showed hyperperistalsis and tenderness over the duodenum with a marked defect and spasm in the duodenal cap. On medical treatment the symptoms disappeared. On account of the positive findings, however, the patient is listed as having a recurrent ulcer.

over the traumatized area, necessarily interferes with normal gastric peristalsis; whereas, when a gastro-enterostomy is done and the pyloric portion of the stomach is not operated upon, the immediate emptying of the stomach is better. When this unsatisfactory emptying occurs it usually exists for only a few days, and is readily overcome by periodic gastric lavage. As a rule,

after pyloroplasty the stomach should be washed out every six or eight hours for the first day or two. If after forty-eight hours there is but little retention the lavage is discontinued, or if there is a moderate amount it is done at longer intervals. In some cases there seems to be no necessity for gastric lavage, though it is usually well to be on the safe side and wash out the stomach at least a few times. Normal salt solution in which there is about

FIG. 73.—TRACING FROM ROENTGENOGRAM OF STOMACH OF MR. W. J. B., TAKEN 25 DAYS AFTER GASTRO-ENTEROSTOMY.

In this case, there was no permanent improvement after pyloroplasty, because of persistently recurring adhesions. The pyloric end of the stomach was occluded with a kangaroo tendon, and a gastro-enterostomy was done. The fluoroscope shows some passage of food through the pylorus. The patient is now complaint-free.

a dram (4 c.c.) of sodium bicarbonate to the quart (liter) of water is used for the lavage. Not more than 6 or 8 ounces (200 to 250 c.c.) should be introduced into the stomach at once, and this under very low pressure. There is, however, very little danger of injuring the sutured area of the stomach, particularly if the first lavage is not given for six or eight hours after the operation, for by then in a properly sutured wound the peritoneum has poured out a sufficient amount of exudate to reinforce the sutures. Experimental work has shown that the sutured intestine is stronger twenty-four hours after

the operation than forty-eight hours after the operation, because in the second twenty-four hours the lymphatic exudate has somewhat softened but the permanent organic union of the wound has not really begun. By the end of the third or fourth day, the union is quite strong. If the wound in the stomach has been properly sutured there is no real danger from careful

FIG. 74.—TRACING FROM ROENTGENOGRAM OF STOMACH OF MR. L. W. P., TAKEN 19 MONTHS AFTER GASTRO-ENTEROSTOMY, WHICH WAS PERFORMED BECAUSE OF LACK OF IMPROVEMENT OF CLINICAL SYMPTOMS AFTER PYLOROPLASTY.

There were many adhesions. The pylorus was occluded with a stout kangaroo tendon. About half of the food now goes through the pylorus. The patient is now complaint-free.

gastric lavage. If it has been improperly sutured it will probably leak whether gastric lavage is done or not.

For the first few months there is often not complete relief from gastric symptoms after pyloroplasty. This is doubtless due to the same reason that it takes a broken leg a good many months to recover normal function even though the bones may have been properly set and are in good alignment. Around the sutures in the stomach exudate will occur and there will be

reaction in the wound for several weeks. There is hyperemia from repair, which leaves the tissues somewhat more sensitive to strain and to muscular work. These are the natural consequences of such an operation, but after they have passed off, which is usually within two or three months, the eventual

FIG. 75.—TRACING FROM A ROENTGENOGRAM OF THE STOMACH OF MR. G. B. S.
This patient was not relieved by pyloroplasty. There was a recurrent ulcer near the wound from the pyloroplasty. The ulcer was excised, the tissues were infolded and sutured, and a gastro-enterostomy was done. This roentgenogram was taken nine months after the gastro-enterostomy. Practically no food passes through the pylorus. The patient is now complaint-free.

result more nearly resembles an entirely normal stomach in which there has been no pathology than could obtain after such operations as gastro-enterostomy or resection.

In a few cases there is a recurrence of the ulcer in pyloroplasty (Figs. 71, 72). This has already been alluded to and in properly selected cases is doubtless due to injuring or suturing the pyloric mucosa. The change in the

FIG. 76.—TRACING FROM A ROENTGENOGRAM OF THE STOMACH OF MR. J. C., TAKEN TEN MONTHS AFTER GASTRO-ENTEROSTOMY AND OCCLUSION OF THE PYLORUS WITH A KANGAROO TENDON.

He was not relieved by pyloroplasty. There was a recurrent ulcer in the upper duodenal border about one half inch from the pylorus. Fluoroscopic examination shows very little food going through the pylorus, a large majority of it leaving through the gastro-enterostomy. The patient is now complaint-free. Of these three cases in which kangaroo tendon was used, the occlusion in one case seems to be almost complete after ten months. In the presence of recurrent ulcer or marked adhesions, simple ligation of the pylorus appears to make a more effective occlusion than is obtained experimentally in the normal stomach of an animal. (The four preceding figures are from a paper by J. Shelton Horsley entitled "The Choice of Operations for Gastric and Duodenal Ulcers," *Journal American Medical Association*, Sept. 15, 1923, Vol. 81, pp. 912-918.) The roentgenologic examinations and reports of all these pyloroplasties were made by Dr. Fred M. Hodges.

technic from that first employed when the pyloric mucosa was sutured will probably greatly decrease if not eliminate the incidence of recurrent ulcers after this pyloroplasty. Even if they do occur, however, their treatment is much simpler than would be the treatment of jejunal ulcer.

John F. Erdmann, of New York, has recorded his results after this pyloroplasty. He has done this operation in 60 cases with only 2 deaths,

one death being due to pneumonia and the other to gas bacillus infection. He has been able to trace 84 per cent of the patients, and finds that 94 per cent of them have resulted in apparently entire clinical cures. This seems to show that the operation has a distinct field, and in other hands than those of its originator the proportion of successful results is most gratifying.

When a recurrent ulcer does occur it may be treated in one of several ways. If there are many adhesions and some infiltration of the surrounding tissues a good practice is to place a stout kangaroo tendon around the pyloric end of the stomach, slightly on the oral side of the ulcer, and tie it just enough to occlude the stomach without injury to the tissues. Then a posterior gastro-enterostomy is done. If there are no adhesions and the ulcer is well localized it may be excised. If the tissue on the gastric side of the pyloroplasty scar appears thickened, or if the ulcer is gastric and in such a location that it does not lend itself well to excision, a pylorectomy should be done. I have tried all of these methods in recurrent ulcers after pyloroplasty, attempting to employ the method that seemed best suited to the individual case, and have found the results satisfactory (Figs. 73-76).

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# CHAPTER XI

## GASTRO-ENTEROSTOMY

The indications for gastro-enterostomy in ulcer of the pylorus have already been discussed, but it may not be inappropriate briefly to recall them. When the ulcer is on the duodenal side of the pylorus and is extensive, or when there is marked infiltration of the duodenum and surrounding tissue, or when adhesions are abundant and extend beyond the gall-bladder, or when the stenosis is marked, a posterior gastro-enterostomy gives excellent results and should be preferred to pyloroplasty.

This operation is done either with or without clamps. The clamps have long soft blades made for this special purpose, and are often covered with rubber tubing in order to avoid injury to the stomach wall. Stomach clamps, such as the Roosevelt, have been extensively used. It has a central, rather large, rigid portion with an elastic steel blade on two sides. The stomach is brought down and fixed on one side of the central part of the clamp by the upper blade, and the jejunum is fixed on the other side. The objections to this type of clamp are that after the tissues have been fixed they cannot be readily readjusted in the course of suturing, and that the central portion being rigid is more likely to injure the tissues within its grasp than if they were clamped by forceps both of whose blades were elastic. There is a tendency to dispense with stomach clamps in gastro-enterostomy. They fix the tissue in position and render the operation bloodless, but their disadvantages apparently overbalance these favorable features. First of all, even a clamp with the softest blades bruises the stomach and jejunum to some extent. The gastric and jejunal mucosa are delicate structures and prone to injury. In a gastro-enterostomy the physiologic conditions of the jejunum are changed because the acid contents of the stomach are poured directly into the jejunum, which is accustomed to alkaline contents. Any injury in the presence of such an unphysiologic condition is more likely to be accentuated and to be difficult of repair than if the physiology had not been altered. In other words, the presence of the clamp may give rise to a trauma that will result in a jejunal ulcer. Perhaps the most serious objection to the clamps, however, is the fact that they conceal hemorrhage; even though the clamps may be relaxed slightly before the wound is entirely closed, a bleeding vessel may be temporarily occluded by the pressure and later will bleed. If the operation is done without clamps and the bleeding controlled by accurate suturing, secondary hemorrhage is much less likely to occur. Then, too, if the stomach is small, it requires considerably more trauma to pull down the stomach and apply the clamps than if the operation be done without the clamps when it is

not necessary to deliver so much of the posterior gastric wall into the abdominal incision.

The incision for gastro-enterostomy is somewhat the same as for a pyloroplasty, only it need not extend quite so high in the abdomen, and may be a little nearer the midline. The incision should not be made directly in the midline, as the tissues here are thin and healing is not so satisfactory as when it goes through a portion of the recti muscles. The transverse colon with its attached omentum is identified and delivered into the wound. Its mesocolon is put upon a stretch while the part of the stomach to be opened is shoved down with the hand to press upon the transverse mesocolon, which is divided in some avascular space large enough to permit an ample stoma for the gastro-enterostomy. This is preferably almost directly above the beginning of the jejunum, though it may be a little to one side. The incision through the mesocolon is enlarged from before backward and the posterior wall of the stomach is delivered through it. A point is selected where there is ample surface for the gastro-enterostomy, and yet sufficiently near the pyloric end of the stomach to obtain the benefits of some of the normal stomach digestion (Fig. 77). If the opening is too large and placed directly below the esophageal orifice the stomach may empty its contents so quickly that no gastric digestion results. In unusual instances this may produce considerable pain and result in what is known as a "dumping stomach." There is no necessity for the extremely long stoma of 4 or more inches (10 cm.) that was formerly made in gastro-enterostomy. An opening of 2.5 inches (6.3 cm.) is enough. This affords sufficient exit for the gastric contents and permits a certain amount of contraction without interfering with satisfactory emptying.

FIG. 77.—DIAGRAM SHOWING THE GENERAL POSITION AND DIRECTION OF THE STOMA IN GASTRO-ENTEROSTOMY.

The posterior part of the rent in the mesocolon is sutured to the upper portion of the posterior surface of the stomach delivered through this rent with a few interrupted sutures of plain or tanned catgut. This procedure, which was originally suggested by McArthur, is much better than an attempt to do this suturing after the gastro-enterostomy has been completed (Fig. 79). If no sutures are placed in this area there may eventually be a hernia of the small intestines through the opening into the lesser peritoneal cavity; in the earlier days of posterior gastro-enterostomy such cases were reported.

A point in the posterior wall near the lesser curvature, and another about 2.5 inches (6.3 cm.) from this, anterior and to the left near the greater curvature, are clamped with Allis forceps. If the stomach has been greatly dilated the stoma may be made longer than 2.5 inches (6.3 cm.), for it will doubtless contract in proportion to the rest of the stomach when the dilatation recedes because of the overcoming of the obstruction of the pylorus by the stoma of the gastro-enterostomy. In the average case, however, a stoma of 2.5 inches (6.3 cm.) suffices.

The selection of the upper jejunum is important. While as W. J. Mayo so well pointed out many years ago there should be no distinct intestinal loop in a posterior gastro-enterostomy, it is also unwise to select the jejunum to be involved in the gastro-enterostomy so close to its origin that free motion of the stomach will not be permitted. Tension on this short segment of jejunum between its origin and the stoma may produce disagreeable symptoms. In the average case a distance of about 3 inches (7.7 cm.) from the origin of the jejunum to the point of its approximation to the stomach is satisfactory. This will prevent tension and at the same time will not cause a loop in which duodenal contents may be retarded.

If it has been decided to use clamps, the posterior wall of the stomach is pulled well into the wound and a clamp applied so that the heel of the clamp is near the lesser curvature and the point toward the greater curvature, placed in such a direction that the opening in the stomach will be from above downward and to the left. The loop of jejunum is clamped and placed beside the clamp on the stomach in such a way that the upper portion of the incision in the jejunum will be sutured to the upper portion of the incision in the stomach. In this way the stoma of the gastro-enterostomy will be from above downward and to the left. After the clamps have been satisfactorily adjusted the transverse colon and its mesentery are returned within the abdominal cavity and packed off in the upper epigastric and hypochondriac regions.

The clamped loop of jejunum, with its oral end at the point on the clamped portion of the stomach near the lesser curvature, is united to the stomach with a continuous right-angle suture of 00 tanned catgut, beginning on the patient's right. The short end of the knot is clamped and the suture is continued, taking a backstitch after every few stitches to lock the line of sutures. This may be done with a curved intestinal needle or with a straight needle. When the bowel and stomach have been united the line of sutures is further locked by an additional backstitch and the suture is clamped with mosquito forceps and laid aside temporarily. The surrounding tissues are well packed off with moist gauze and an incision is made in the stomach about 2 or 2.5 inches (5 or 6.3 cm.) and about a centimeter from the line of sutures (Fig. 78). Any gastric contents in this clamped portion of the stomach are gently removed with sponges. The jejunum is similarly incised and its contents are removed.

The posterior margin of the wound in the stomach is united to the posterior margin of the wound in the jejunum with a continuous lockstitch

of No. 1 tanned catgut. As the first layer of sutures began on the patient's right, it is probably better, though not essential, to begin this row at the left extremity of the wound. The row of sutures is continued as a continuous lock or buttonhole stitch, holding the thread snugly so as to control bleeding. When the suturing of the posterior portion of the wound has been completed the stitch is continued anteriorly, catching a small margin

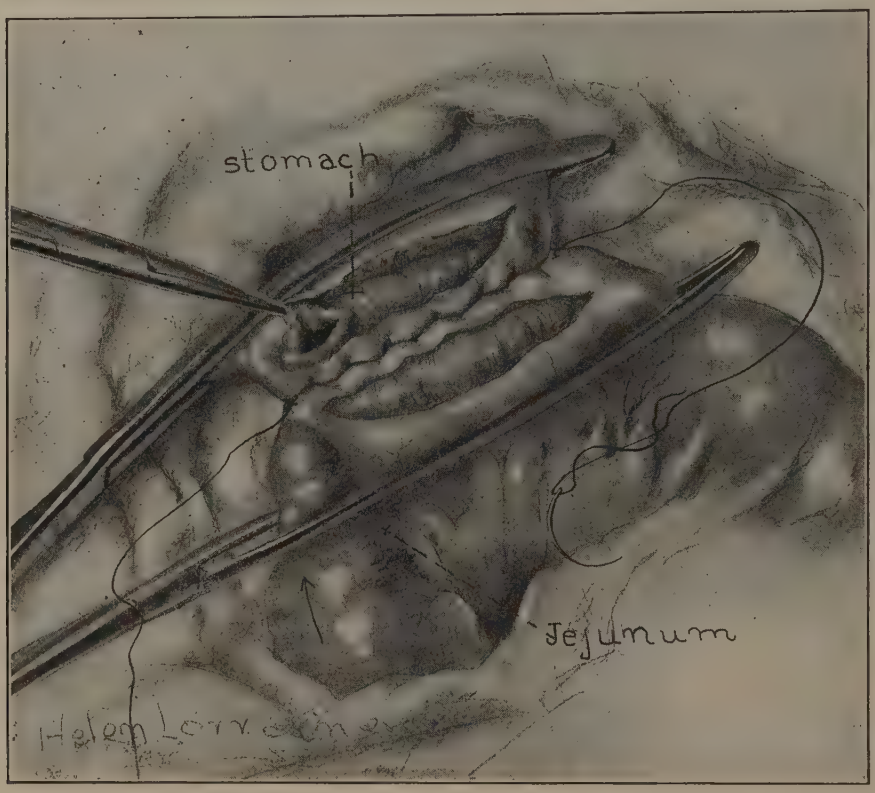


FIG. 78.—THE STOMACH HAS BEEN DELIVERED THROUGH THE RENT IN THE MESOCOLON.

Clamps have been applied and the stomach and jejunum have been united with a row of continuous mattress sutures. An incision is being made in the stomach. When clamps are used it is possibly best to carry the incision down to the mucosa before opening the mucosa, as in this way the vessels can be more readily detected and caught. This point, however, is not essential.

of the stomach and of the jejunum in the bite of the stitch. No effort is made to invert the edges of the wound or to obtain peritoneal apposition. The purpose of this row of sutures is to approximate the tissues and to control bleeding. Just before it is completed the clamps, first on the stomach and then on the jejunum, are unlocked and loosened so as to demonstrate whether there are still any bleeding points that have not been controlled by the sutures. This loosening of the clamps should be gently done so as not to flood the wound with the contents of the stomach or bowel. If there is any bleeding

point it is whipped over with tanned catgut in a needle. After this has been done the suture is completed, tied to its original end four or five times and the knot is cut short. The wound is cleaned with sponges moist with salt

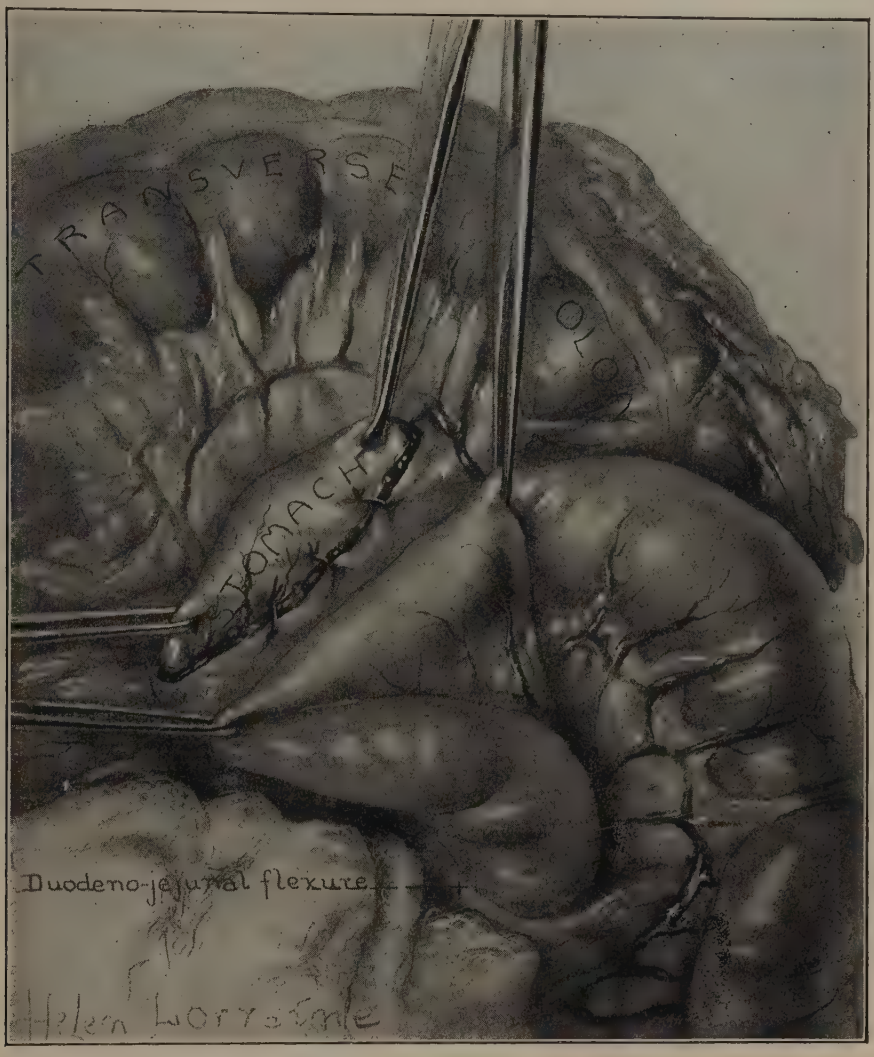


FIG. 79.—GASTRO-ENTEROSTOMY WITHOUT CLAMPS.

A portion of the posterior wall of the stomach has been delivered through the opening in the mesocolon, and its lower part sutured to the posterior border of the rent in the mesocolon.

solution, and if there has been much soiling of the surrounding gauze the soiled gauze is removed and replaced with fresh gauze.

This inner row of sutures is buried by the original outer row of sutures, which is now taken up again and continued anteriorly as a continuous right-angle suture. By depressing the first row of sutures with a hemostat while the stitches of the outer row are being drawn together, inversion is readily

obtained and there is accurate approximation of the peritoneal surfaces. This outer suture is tied to its original end, the knot being tied about four times. An interrupted mattress suture of 00 tanned catgut is placed at each extremity of the wound about a half inch (1.3 cm.) beyond the sutured margin. This is partly to reinforce the suture line and partly to prevent too much angulation at the ends of the gastro-enterostomy. If there seems to be any weak point in the sutures, an additional interrupted stitch may be placed at the suspected spot.

As has already been emphasized, it is highly important not to draw the sutures too tightly. Of course the tissues should be accurately approximated,

Fig. 80.—An Interrupted Mattress Suture of 00 Tanned Catgut Unites the Loop of Jejunum to the Stomach at Each End of the Proposed Incision in the Stomach.

but they should not be white when the suture line is completed. If the suture is too tight it tends to produce necrosis and cut out, and the union is more apt to be satisfactory with gentle approximation than with tight constriction.

A few interrupted sutures of 00 tanned catgut are placed between the upper portion of the rent in the mesocolon and the stomach about a half inch to an inch (1.3 to 2.5 cm.) above the gastro-enterostomy. The omentum and the transverse colon are replaced in the abdominal cavity, and the abdominal wound is sutured in the usual way.

If no clamps are to be used the technic differs in some important details. The delivery of the posterior stomach wall through the opening made in the transverse mesocolon is the same as when clamps are employed (Fig. 79). After the stomach has been delivered and the upper portion of its posterior

wall sutured to the posterior margin of the rent in the mesocolon, a segment of jejunum is selected about 3 inches (7.7 cm.) from its origin and the oral end of this loop is fastened to the posterior wall of the stomach near the

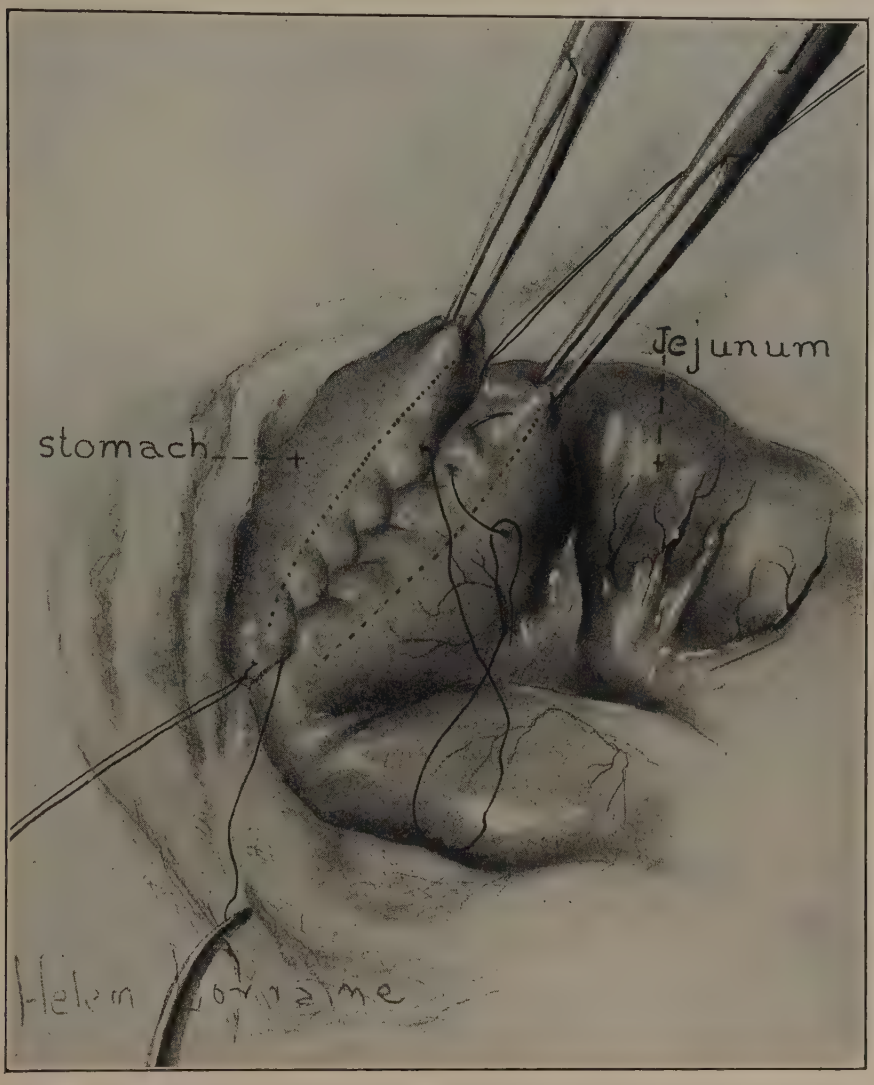


FIG. 81.—THE STOMACH AND JEJUNUM ARE UNITED BY A CONTINUOUS RIGHT-ANGLE SUTURE OF 00 TANNED CATGUT, WITH AN OCCASIONAL BACKSTITCH.
The site of the incision into the stomach and duodenum is represented by dotted lines.

upper curvature with a single mattress suture of 00 tanned catgut. A second similar suture is placed about 2½ or 3 inches (6.3 or 7.7 cm.) lower down on the jejunum, fixing it to the posterior wall of the stomach near the greater curvature in such a way that the direction between these two points would be from above downward and to the left, as would be the stoma after the use

of clamps in gastro-enterostomy (Fig. 80). While holding these two sutures taut, the loop of jejunum is united to the posterior surface of the stomach with a continuous right-angle suture of 00 tanned catgut (Fig. 81).

The tissues are packed around with moist gauze, and traction is maintained on the two interrupted sutures so as to hold the stomach and intestine taut. An

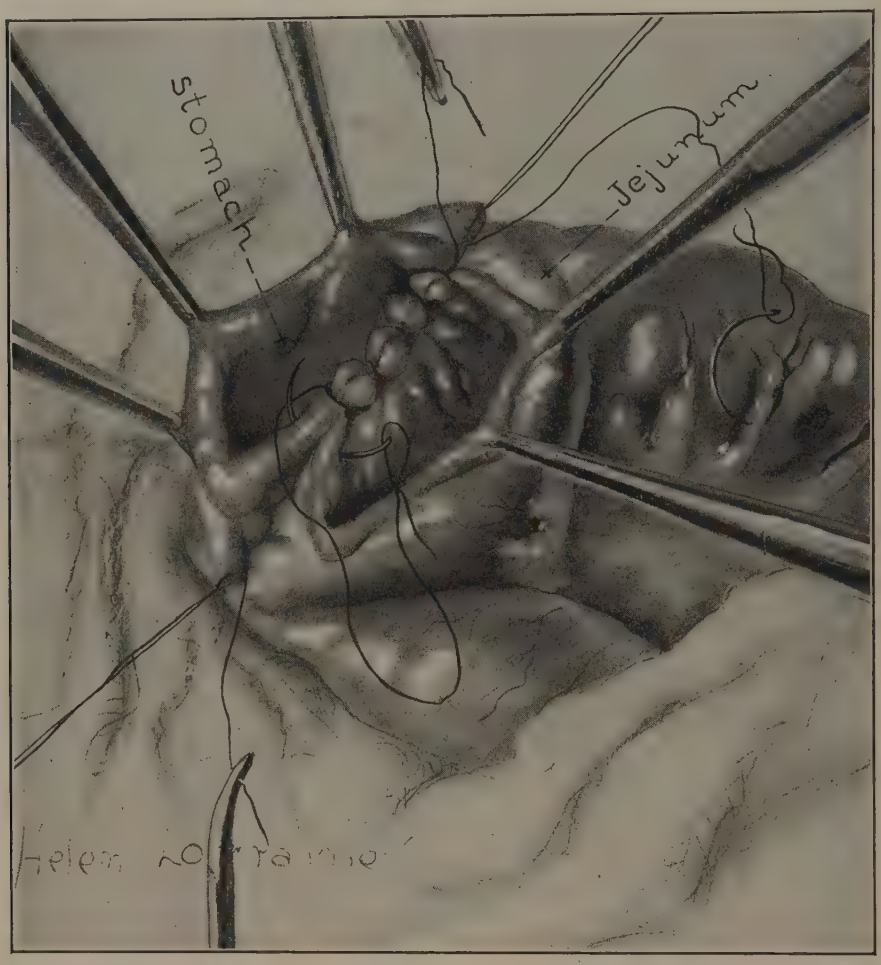


FIG. 82.—THE INCISION INTO THE STOMACH AND JEJUNUM HAS BEEN MADE IN SECTIONS AS DESCRIBED IN THE TEXT.

The posterior margin of the incision in the jejunum is united to the posterior margin of the incision in the stomach with a continuous lockstitch of tanned catgut.

incision is made into the stomach about the middle of the proposed stoma. It is at first about one-half inch (1.3 cm.) long and about one-third inch (0.8 cm.) from the line of sutures. The bleeding points are caught with small Ochsner forceps and gas and gastric contents are quickly removed with a suction apparatus. The incision is continued first toward one end and then toward the other, cutting about a half inch (1.3 cm.) at a time,

and clamping the vessels accurately as they are cut. In this way the incision can be readily made about 2 or 2½ inches (5 or 6.3 cm.) long and the bleeding is controlled as the incision is being made. By a similar procedure an incision of the same length is made in the jejunum. If there is any tendency for fluid contents to regurgitate into the wound, either from the stomach or from the jejunum, it is quickly removed with the suction

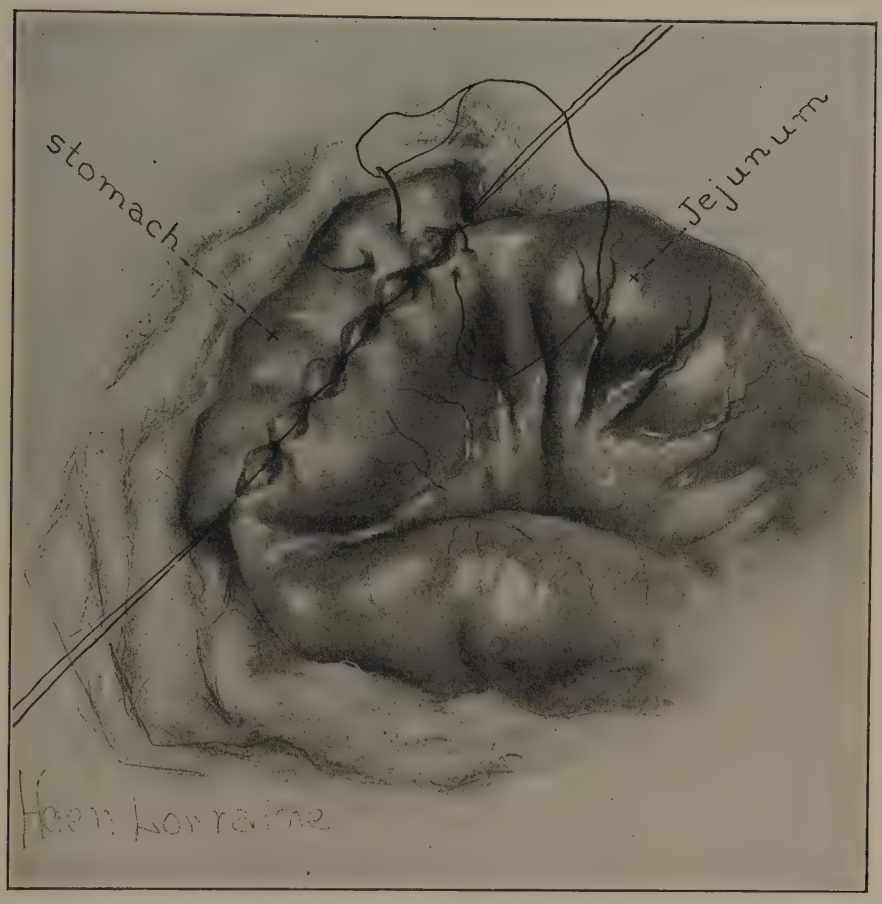


FIG. 83.—THIS SUTURE IS CONTINUED ANTERIORLY, BY TAKING A SMALL BITE OF TISSUE IN ITS GRASP AND MAKING NO EFFORT TO INVERT THE MARGINS OF THE WOUND.
It completely controls the bleeding.

apparatus. A continuous lockstitch of No. 1 tanned catgut is begun, preferably at the left end of the wound, and unites the posterior margin of the wound in the stomach to the posterior margin of the wound in the jejunum, being continued as a lockstitch held snugly (Fig. 82). It is so placed as especially to grasp the points that have been clamped, the clamps being removed as the suture proceeds. When the posterior portion of the wound has been sutured the suture is continued anteriorly in a similar manner as in gastro-enterostomy with clamps. Small margins of the tissues are taken with each

bite of the needle. The hemostats are removed as the suture proceeds and any bleeding point that is not controlled by the regular application of the suture is whipped over by a backstitch of the same suture. When this row is completed the long end of the suture is tied four or five times to the original end (Fig. 83).

The rest of the procedure is identical to that of gastro-enterostomy with clamps, which has already been described.

The advantages of this technic without stomach clamps are the more accurate control of bleeding, a better view of the interior of the stomach and jejunum, and the avoidance of trauma from the clamps.

The advantages of accurately controlling the bleeding in the anterior half of the wound are very real, because in many cases in which immediate postoperative bleeding has been reported after posterior gastro-enterostomy, it has been found that the bleeding usually came from the anterior margin of the wound in which there had been an effort to invert the tissues while at the same time attempting to approximate them and secure hemostasis. All of these three things cannot well be done with the same row of sutures, and the union is just as strong when no effort is made to invert the margins of the wound with the inner row which is buried by the outer line of sutures, as when peritoneal approximation is attempted by both rows. If the stoma of the gastro-enterostomy could be visualized it would be readily seen that when the tissues in the anterior portion of the gastro-enterostomy are approximated as has been described, the sutures in this portion of the wound show but little if at all within the lumen of the gastro-enterostomy stoma. Then, too, the raw margin of the sutured wound is exposed on the surface and bleeding can be readily detected while applying the second row of sutures. The presence of the margin of the cut stomach and jejunum on the peritoneal surface doubtless incites an unusual amount of peritoneal exudate and so makes for a stronger union than if the raw surface had been turned into the lumen of the gastro-enterostomy. For these three reasons, then, this type of suture seems preferable: (1) the better control of hemorrhage; (2) the absence of the line of sutures or the raw margin from the anterior portion of the wound within the stoma of the gastro-enterostomy; (3) the more abundant exudate that is probably thrown out because of the presence of the raw margin of the cut stomach and jejunum on a buried peritoneal surface. Of these three reasons the strongest is the control of hemorrhage. There seems to be no real justification for continuing the practice of inverting the margins of the anterior part of a gastric or intestinal wound with the inner row of sutures when two or more rows are used.

Anterior gastro-enterostomy is occasionally, though very rarely, indicated. This happens when the pyloric end of the stomach is too much diseased to permit of a pyloroplasty, and when there are extensive adhesions or pathologic lesions in the posterior wall of the stomach. Here a loop of jejunum about 10 or 12 inches (25.5 to 30.5 cm.) from its origin is brought up in front of the transverse colon and sutured to the anterior surface of the stomach by the technic described for suturing these structures in posterior gastro-

enterostomy. The loop of jejunum should be so chosen as to produce no marked tension, yet it should be as near the origin of the jejunum as is practicable.

After the anastomosis has been completed an additional interrupted mattress suture placed about an inch (2.5 cm.) from each end of the stoma may prevent kinking at these points. In order to avoid the so-called vicious circle, it might be well to make an entero-anastomosis by joining the two limbs of the jejunum that go to the gastro-enterostomy. This is done by an incision about an inch or an inch and a half (2.5 to 3.8 cm.) long in each limb of the jejunum made at a point just below the level of the transverse colon. The technic for entero-anastomosis is described on page 288. A serious objection to this procedure is that it will divert a considerable portion of duodenal contents and so leave the portion of the jejunal mucosa opposite the stoma of the gastro-enterostomy partially unprotected by the alkaline contents of the duodenum. In these cases, however, this may be a minor consideration, for if the entero-anastomosis is made no longer than an inch (2.5 cm.) it doubtless would not sidetrack all of the duodenal contents, and as the conditions for which anterior gastro-enterostomy is made would be serious, probably cancer, the acidity of the contents of the stomach would usually be low or absent.

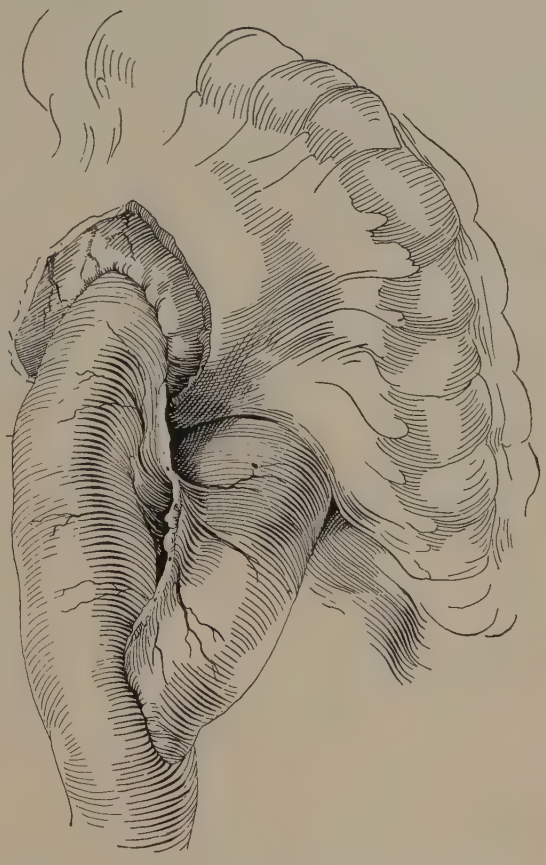

Fig. 84.—The "Y" or Roux Gastro-enterostomy.
The jejunum has been divided about six inches below its origin, and the distal end sutured to the posterior wall of the stomach. The proximal end is united end-to-side to the jejunum lower down.

Gastro-enterostomy of the "Y" or Roux type is but seldom done. In this operation the jejunum is doubly clamped and divided, about 6 inches (15.3 cm.) below its origin. The lower end of the jejunum is sutured to the posterior wall of the stomach, which has been previously exposed through an opening in the transverse mesocolon as described in the technic for posterior gastro-enterostomy. The upper end of the jejunum is then united, end-to-side, to the jejunum lower down (Fig. 84). The great objection to this operation,

aside from the rather extensive suturing, is that the end of the jejunum which is united to the posterior wall of the stomach is entirely unprotected from the acid of the gastric juice by the alkaline contents of the duodenum which empty into the jejunum lower down. Possibly some reflux may occur, but this is uncertain, and it does not seem that with reflux so much of the alkaline duodenal contents would appear in the segment of the jejunum united to the stomach as would be brought there with an anterior or a posterior gastro-enterostomy, even though an entero-anastomosis had been done, provided the entero-anastomosis was not too large.

## COMPLICATIONS AND SEQUELÆ OF GASTRO-ENTEROSTOMY

**Jejunal Ulcer.**—The immediate recovery from a gastro-enterostomy is often more satisfactory than from a pyloroplasty, and the patient for the first few months after a gastro-enterostomy is more likely to be free from disagreeable symptoms than after a pyloroplasty. The reasons for this have been already discussed. If the gastro-enterostomy has been done with an open pylorus there is great probability of subsequent trouble, though it may not develop for many months, or even years, after the operation. If the pylorus has been occluded by stenosis or by operation, the duodenal contents are delivered to the stoma of the gastro-enterostomy with a maximum alkalinity, and consequently will protect this mucosa from the acidity of the gastric juice. If, however, the pylorus is open, a portion of the gastric juice goes through the pylorus and lowers the alkalinity so that when the duodenal juice is conveyed to the jejunum opposite the stoma of the gastro-enterostomy its alkalinity is so weak that it cannot fully counteract the acidity from the stomach. In this manner the acid gastric juice has a direct effect upon the mucosa of the jejunum, which is accustomed only to alkaline material. This unphysiologic condition often results in irritation and congestion, which may produce symptoms even if there be no actual ulcer present and, when continued, may result in a jejunal ulcer (Figs. 53, 54). Just what is the proportion of jejunal ulcers after gastro-enterostomy with an open pylorus has never been ascertained. The statistics of R. Lewisohn, of Mt. Sinai Hospital, New York, and of D. L. Davis, concerning the incidence of jejunal ulcer, have been given in Chapter IX.

The symptoms of jejunal ulcer are somewhat similar to the symptoms of a duodenal or gastric ulcer, though the pain is usually located lower. Jejunal ulcers often tend to burrow. Occasionally a jejunal ulcer opens into the transverse colon, and several cases have been reported in which a fistulous tract communicated between the stomach, jejunum, and transverse colon. Such conditions make operation exceedingly difficult. Of course they should be suspected when the patient vomits material normally found in the colon. An enema of barium which quickly appears in the stomach can be readily detected by a roentgenologic examination and the diagnosis in this way is easily made.

If the distinct fields for pyloroplasty and for gastro-enterostomy are recalled, there will doubtless be but small occasion for jejunal ulcer, which rarely if ever occurs when there is complete stenosis of the pyloric end of the stomach or duodenum, but is often found after an open pylorus in conditions where a pyloroplasty would be indicated. If, however, there are border-line cases and it is difficult to make a decision whether a gastro-enterostomy or a pyloroplasty should be done, it should be borne in mind that it is much safer for the patient and easier for the operator to excise a recurrent ulcer after pyloroplasty, to occlude the pylorus by a kangaroo tendon and to do a posterior gastro-enterostomy, than it is to uncouple the gastro-enterostomy, suture the wound in the jejunum and in the stomach, and then do a pyloroplasty.

**"Dumping Stomach."**—Another very serious late sequela of gastro-enterostomy, particularly if this operation is done in a nervous patient and if a wide stoma is made, is the so-called "dumping stomach." Attention has been called to this by several writers, particularly by E. and W. Andrews and C. L. Mix. In such cases the stomach empties almost immediately into the jejunum through the gastro-enterostomy stoma and quickly dilates the jejunum, causing pain. In exceptional instances a mixture of barium and buttermilk will pass out of the stomach in thirty seconds, though this is unusual.

This "dumping stomach" is found more frequently in neurotic patients. The condition readily suggests itself when it is known that a gastro-enterostomy has been performed, that the patient is of a neurotic disposition, and that pain appears in the epigastrium almost immediately after the intake of food in moderate quantities.

In a patient of mine this condition was very marked. The patient gave a history of three previous operations on the stomach before he consulted me. The first operation was done for an ulcer of the stomach near the pylorus. The ulcer appears to have been excised or cauterized, and a posterior gastro-enterostomy was performed. Later, the patient having symptoms, it was thought that the gastro-enterostomy stoma was insufficient so it was enlarged; still later a pylorectomy was done. When the patient, who was of a neurotic type, consulted me the pain was so marked after the ingestion of a moderate amount of food that he dreaded to take food, and consequently limited himself in diet. There was marked emaciation, though he was naturally of the lean type. Roentgenologic examination showed a huge dilatation of the jejunum opposite the gastro-enterostomy stoma. The pylorus had been previously resected. The barium mixture in the stomach was quickly poured into the jejunum, which dilated, causing pain. The pain was relieved as the jejunum gradually carried off the food within a few hours. At operation I disconnected the gastro-enterostomy stoma and sutured the stomach and jejunum. Another opening of about 2 inches (5 cm.) was made in the jejunum and this was sutured to a similar incision in the stump of the stomach at the lesser curvature, so that this opening would be so far as possible opposite to the chief axis of the peristaltic waves and pressure, which

is along the lesser curvature. The stomach was then in a condiiton to empty more nearly normally than when it merely acted as a passage for the quick transit of food from the esophagus to the jejunum, because the gastric conditions were more nearly physiologic. The operation greatly improved the patient's symptoms and complaints and made him much more comfortable, though it did not completely cure him. He can take food now with comparative comfort, and does not have the dread of the immediate pain that formerly followed after the ingestion of a meal.

**Vicious Circle.**—The complication of vicious circle after posterior gastro-enterostomy was formerly rather common when there was a long loop of jejunum between the beginning of the jejunum and its anastomosis with the stomach. A loop of jejunum 6 inches (15.3 cm.) long would often act as a water-trap and fill with duodenal secretions which would regurgitate into the stomach through the pylorus or empty into the stomach through the gastro-enterostomy stoma. The vicious circle was to all intents a type of obstruction. In such cases there was usually also some fault in the technic of the anastomosis, so that there would be a valve or kink which prevented a satisfactory opening into the distal part of the anastomosed loop of jejunum. This resulted in an obstruction in which the duodenal contents accumulated and poured into the stomach and unless the obstruction was relieved the patient died. With the improvement in the technic of posterior gastro-enterostomy, such a complication is now very rare. This improvement consists chiefly in eliminating the long loop that was formerly used and which was very prone to become kinked or obstructed. After this loop was eliminated posterior gastro-enterostomy was known as the "no-loop" operation. Making the opening downward and somewhat to the left in the usual natural axis of the upper portion of the jejunum also helps to avoid a vicious circle. An additional suture at each end of the gastro-enterostomy opening to prevent a sharp kinking where the bowel leaves the stoma tends to prevent valve formation.

In the enthusiasm for eliminating the loop, however, the opposite of this error has sometimes been committed by making the anastomosis too close to the beginning of the jejunum and consequently interfering with the normal motion of the stomach. If, for instance, the stomach is much dilated and the anastomosis is made close to the beginning of the jejunum in an effort to eliminate the loop, when the stomach has contracted there will be tension on the jejunum and more or less serious consequences may result. The technic of the operation as now performed should include the anastomosis of the jejunum at about 2½ or 3 inches (6.3 or 7.7 cm.) from its origin. This gives a very short loop, not sufficiently long to become kinked. It can empty itself readily, and at the same time will permit of a certain amount of play so that if the stomach contracts there will not be undue tension.

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## CHAPTER XII

## EXCISION OF ULCERS OF THE STOMACH; MID-GASTRIC RESECTION; HOURGLASS STOMACH

### EXCISION OF ULCERS OF THE STOMACH

Excision of ulcers of the stomach must be varied according to the size and location of the ulcer. A small ulcer along the lesser curvature, which is the usual location of gastric ulcers, can be excised with a diamond-shaped or oval incision. Whenever an ulcer of the stomach is excised, unless a "sleeve" resection is done, the operation should be accompanied by pyloroplasty, for reasons that have been elaborated in discussing the indications for pyloroplasty, in order to give as much physiologic rest as possible to a stomach whose function has been impaired by the trauma of the operation.

The "sleeve" or mid-gastric resection of the stomach is a typical operation and should be performed when the ulcer is extensive or when it is so large that its excision by a V-shaped, or, rather, a diamond-shaped incision would involve more than a third of the circumference of the stomach. In the latter instance the peristaltic waves, which focus chiefly along the lesser curvature of the stomach, are temporarily abolished at the region of the excision, whereas peristalsis along the greater curvature is not affected. In this way the harmony of the peristalsis is so seriously interfered with that the gastric motor function is greatly impaired, and it would be better to make a "sleeve" resection of the entire circumference of the stomach, thereby interrupting the continuity of all of the wall of the stomach at this level and so giving the same obstruction to all of the peristaltic waves. With the obstruction alike at all levels the peristalsis is better coördinated than if only one half of the stomach wall had been incised and the other half not injured.

When the ulcer is small and on the anterior surface near the lesser curvature, an incision is made in the gastrohepatic omentum and the portion of the stomach containing the ulcer is mobilized and packed around with moist gauze. The vessels along the lesser curvature, including the gastrohepatic omentum, are doubly tied and divided. The vessels at the margin of the ulcer are tied. An incision is made around the margin of the infiltrated area which apparently represents the ulcer. This incision is carried down to the mucosa, but not into it, and the bleeding vessels are clamped as the incision is made. After the coats of the stomach have been divided in this manner and the mucosa bulges into the incision, the mucosa itself is incised, preferably with the electric cautery. This gives a good view of the interior aspect of the ulcer, and the incision is continued in the mucosa so as to include all of the ulcer and a small adjacent margin of apparently healthy

mucosa. If the vessels are carefully caught it will usually be found that they reside in the muscular coat and in the submucosa, and not in the mucosa. A vessel actually bleeding from the margin of the mucosa should, of course, be whipped over with catgut in a needle. The wound is best closed by not suturing the mucosa, but by approximating the divided peritoneal and muscular coats of the stomach as described in the technic on pyloroplasty, with a continuous suture of No. 1 tanned catgut. The hemostats are removed as the points that they clamp are reached with the suture. After this row has been completed it is inverted by a second row of sutures, applied as a right-angle continuous suture, taking a lockstitch every third or fourth stitch. This is reinforced by bringing over some of the adjacent gastrohepatic omentum and stitching it over this row of sutures, and by suturing together the stumps of the ligated portion of the gastrohepatic omentum along the lesser curvature.

It may be objected to this technic that the margins of the incised mucosa should be accurately brought together with sutures. This seems to be an instance in which the desire for mechanical finish of the operation dominates the underlying biologic processes that follow the operation. When the gastric mucosa is sutured snugly enough to control bleeding it undergoes necrosis. The lockstitch, for instance, as used in gastro-enterostomy and applied snugly for hemostatic purposes, causes a necrosis of the mucosa in its grasp. This has been studied experimentally by Mall, Gould, and others, and has been already discussed. The process of repair in such instances consists first of all in sloughing off of the portion of mucosa that is in the grasp of the suture, and then the rapid covering over of the clean raw surface resulting from the removal of the slough by epithelium from the adjacent margins of the mucosa.

In excision of a gastric ulcer there is undoubtedly a tendency to recurrence of the ulcer in the region from which the ulcer was excised. Consequently the mucosa should be treated with the greatest consideration and more carefully dealt with than if the wound were merely an incision in an otherwise healthy stomach. When a wound resulting from the excision of an ulcer can be so repaired surgically that the mucosa bears no suturing and has been subjected to no unusual trauma, it seems obvious that there would be less necrosis and smaller opportunity for a recurrence of the ulcer than if the mucosa had been sutured and so not only traumatized, but deprived of its nutrition by the application of the sutures.

When the ulcer is situated on the posterior wall of the stomach it is often difficult of access. Not infrequently such an ulcer is adherent to the pancreas or the tissues in its immediate neighborhood. Approach must then be made by a wide transverse incision in the gastrohepatic omentum and probably also an incision in the gastrocolic omentum or in the transverse mesocolon (Fig. 85). After packing off the tissues the ulcer is gradually freed by spreading scissors dissection and a suction apparatus should be ready to remove any of the gastric contents that may be evacuated if the cavity of the stomach is opened. The margins of the ulcer are excised and the ulcer is repaired in the manner already described.

The practice of W. J. Mayo of bringing up the great omentum through the gastrocolic omentum and stitching it around the sutured wound in the stomach is excellent. This not only reinforces the sutured stomach wall, but by the peritoneal covered fat prevents close adhesions to the pancreas and so permits mobility for the stomach.

Sometimes the ulcer is near the esophagus, or even in the cardiac end of the stomach. In such instances exposure is extremely difficult and a pro-

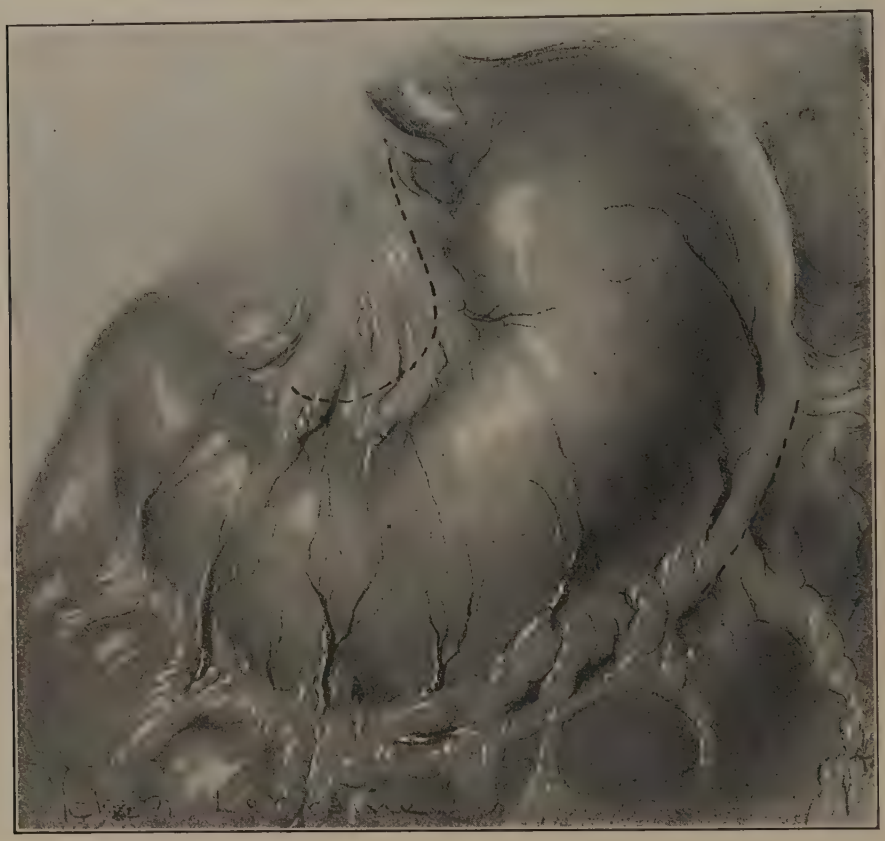

Fig. 85.—The Lines of Incision in the Gastrohepatic and Gastrocolic Omenta for Approach to the Posterior Wall of the Stomach in Excision of an Ulcer.

longed operation may result in trauma and infection which is usually poorly borne by these patients. Here the procedure of Balfour should be adopted. Around the ulcer the gastrohepatic omentum is ligated and freely dissected from the lesser curvature. This exposes the region of the ulcer. After clamping the superficial blood-vessels, a flap of the peritoneal and muscular coat of the stomach is raised over the ulcer. If there is suspicion of malignancy a frozen section is made. If the ulcer is not cancerous, the crater of the ulcer is demonstrated and perforated by a cautery at dull-red heat. The cauterization is continued until the entire surface of the ulcer has been well cauterized. The margins of the burned area are approximated with interrupted

sutures of chromic catgut. The flap of muscle and peritoneum is replaced and held in position with mattress sutures of silk. Finally, the portion of gastrohepatic omentum originally dissected up is sutured over the flap. The Balfour operation has a decided field in ulcers difficult of access but, as in excision of ulcers by other methods, it should be accompanied by some operation, in my opinion preferably a pyloroplasty, in order to give the desired rest to the stomach by facilitating emptying during the healing of the cauterized tissues. Balfour accompanies his operation with a gastro-enterostomy.

## MID-GASTRIC OR "SLEEVE" RESECTION OF THE STOMACH

When a mid-gastric ulcer is too extensive to be dealt with by measures which have just been described, or in certain "hourglass" stomachs, or in cancer in the body of the stomach, a mid-gastric or "sleeve" resection is often indicated. There should be thorough exposure by an incision made from just below the ensiform cartilage to the navel along the inner portion of the right rectus muscle. The gastrohepatic omentum is incised and the vessels along the lesser curvature in the region of the proposed lines of excision are doubly clamped, divided, and tied. It is well to clamp these vessels before tying them, particularly if there is much fat, because the pressure of the clamp has a hemostatic effect and renders the ligature somewhat snugger and safer. The vessels are controlled by transfixing the clamped tissues with No. 1 plain catgut in a round needle and tying the ligature as the clamp is removed. In the larger vessels it is wise to put two ligatures, about one-fourth inch (0.6 cm.) apart. After the lesser curvature of the stomach has been satisfactorily freed, the hand is introduced into the lesser peritoneal cavity, the stomach lifted up, and the gastrocolic omentum is incised, and the vessels are doubly clamped, divided, and tied as along the lesser curvature. All vessels should be tied before the stomach itself is opened. After the region of the stomach to be excised has been detached above and below it is packed off with moist gauze and Payr clamps are applied along the proposed lines of excision. Long, soft-bladed, stomach clamps with or without rubber covering, are placed on the portion of the stomach intervening between the two Payr clamps close to the Payr clamps. The segment of the stomach is removed by incising it along the Payr clamps with the electric cautery.

This leaves the two stumps of the stomach, each held firmly by a Payr clamp. It was formerly the practice to suture the posterior surface of the stomach with interrupted or continuous sutures of silk or linen before removing the clamps. Sutures so placed are subject to strain from subsequent manipulations. The practice of cutting away the margin of the stomach crushed by the Payr clamp is a useless procedure, because it involves an additional loss of blood and because sutures placed through the uninjured wall of the stomach including the mucosa cause a necrosis of the mucosa. If this crushed band of tissue is removed and sutures are applied to the fresh stomach wall, the sutures themselves will produce a margin of necrosis. It

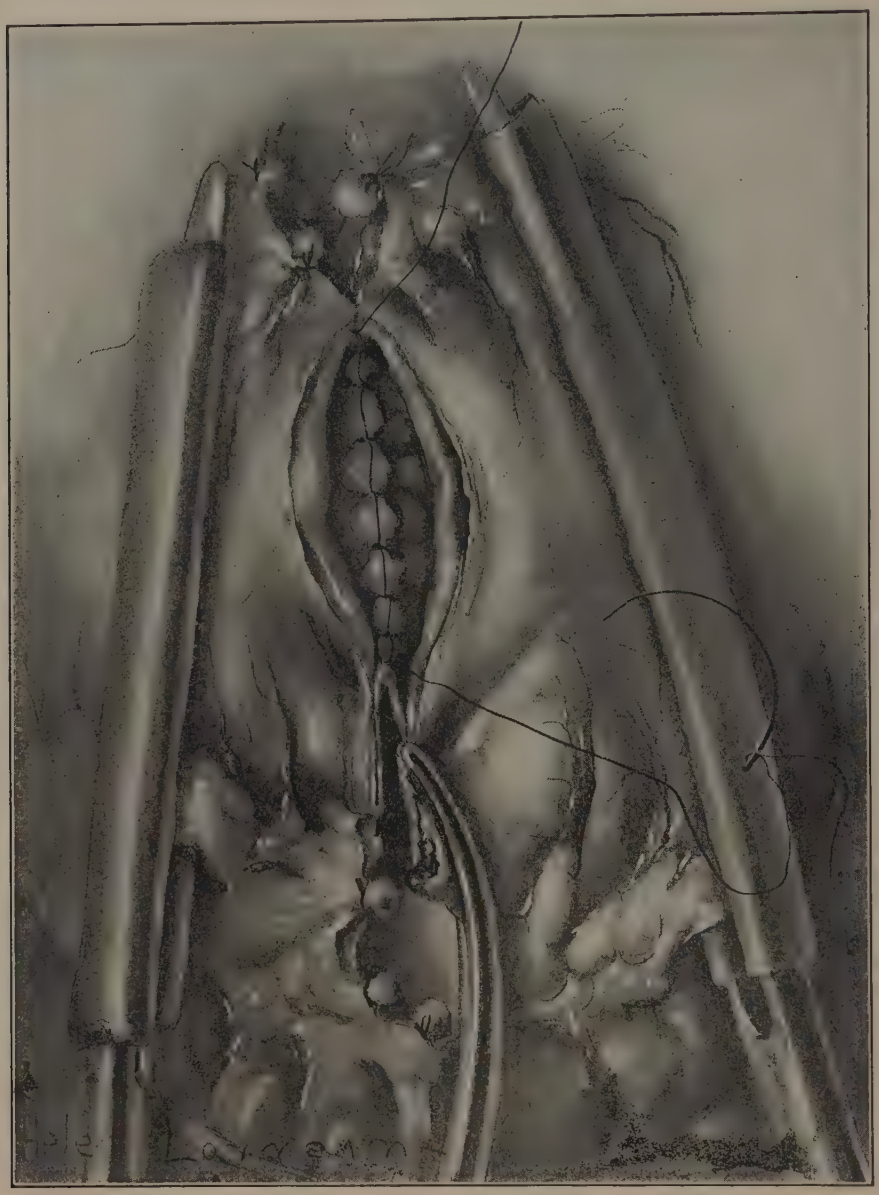

FIG. 86.—THE SEGMENT OF STOMACH HAS BEEN REMOVED.

The soft-bladed forceps have been applied, the Payr clamps released, and the suture of the posterior wall of the stomach is being placed as a continuous lockstitch, penetrating all coats and applied snugly.

is best, then, to apply the sutures along the stumps of the stomach including the portion crushed by the Payr clamp. This makes for an additional hemostatic security and does not materially add to the usual burden of necrotic separation of the sutured portion of the gastric mucosa. In order to prevent flooding the field with gastric contents, the stump of the stomach may be compressed by soft-bladed clamps before loosening the Payr clamps.

FIG. 87.—THE INNER ROW OF SUTURES HAS BEEN COMPLETED BY CARRYING IT ANTERIORLY AND TYING IT TO ITS ORIGINAL END.

No effort is made to invert the margins of the wound. The outer row of sutures is being applied as a continuous right-angle suture with an occasional backstitch.

This is not always necessary and if the resection has been extensive the presence of additional long clamps may make manipulations more difficult. A somewhat better method is gently to remove the Payr clamp on one side

and to clamp the crushed area in segments with ordinary Ochsner forceps. The crushed margins are glued together by the force of the Payr clamps and do not separate very readily.

When both Payr clamps have been removed and the crushed margins caught in segments, a suture is begun at the lesser curvature. This, as has been already emphasized, is the important curvature to approximate accurately

FIG. 88.—THE POSTERIOR WALL OF THE STOMACH IS LIFTED UP AND A CONTINUOUS SUTURE OF 00 TANNED CATGUT IS APPLIED.

because the axis of peristalsis is along the lesser curvature. After opening a portion of the upper part of the left stump of the stomach the gastric contents are removed with a suction apparatus. A similar procedure is repeated on the right side and a suture of No. 1 tanned catgut in a round needle is begun, joining accurately the lesser curvature of both gastric stumps. The suture is continued as a lockstitch, uniting the posterior margins of the walls of the stomach and drawing the suture sufficiently snug to control all bleeding. More of the stumps of the stomach is released from the grasp of the Ochsner

forceps as the suture proceeds (Fig. 86). If there are uncontrolled bleeding points before the suture reaches them they are clamped with Ochsner forceps. When the greater curvature is reached the suture is continued anteriorly in the same manner as it was posteriorly, uniting the anterior walls with a continuous lockstitch. Any large bleeding vessel is whipped over twice. If no stomach clamps have been applied the bleeding will be accurately controlled when the suture is finished. If stomach clamps are used, however, they should be loosened before the suturing is completed on the anterior wall in order to

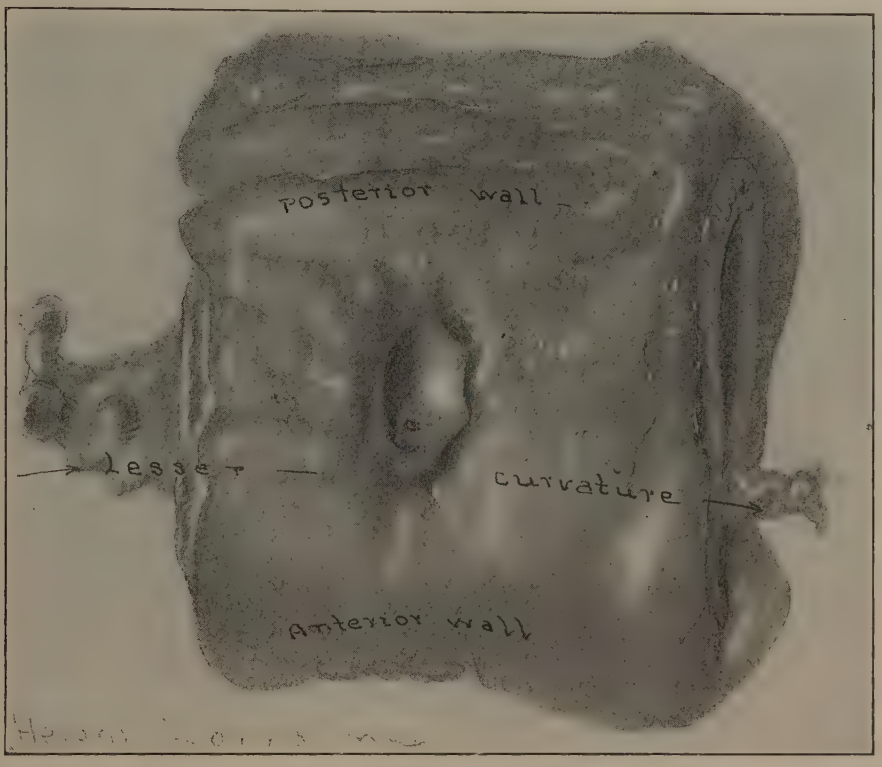


FIG. 89.—INTERIOR VIEW OF A SEGMENT OF THE STOMACH REMOVED BY MID-GASTRIC RESECTION. Note the large ulcer on the posterior wall in contact with the lesser curvature where a vessel is exposed. The ulcer was benign.

determine whether any bleeding points have been left uncontrolled. The suture is tied to the original end four or five times and cut short. The anterior row of sutures is buried with a continuous right-angle suture of 00 tanned catgut, taking a backstitch at intervals to make it more secure (Fig. 87). The posterior surface is then further sutured with a continuous suture of 00 tanned catgut applied preferably as a right-angle suture, though if this is inconvenient the continuous running stitch is all that is necessary. This can be done rather readily with a curved needle (Fig. 88). An interrupted mattress suture is inserted at the greater and at the lesser curvatures, and these are used as tractors, lifting up the stomach and facilitating the application

of the superficial posterior row. This leaves the peritoneal posterior row unaffected by the manipulations that occur in the resection. At the lesser curvature and at the greater curvature additional interrupted sutures of oo tanned catgut are placed to reinforce these points. The stumps of the gastrohepatic omentum and of the gastrocolic omentum are sutured over the wound at the upper and at the lower curvatures, respectively. In this manner additional strength is given the wound at these borders and at the same time the suture lines in these regions where the peritoneum leaves a small uncovered surface is amply protected.

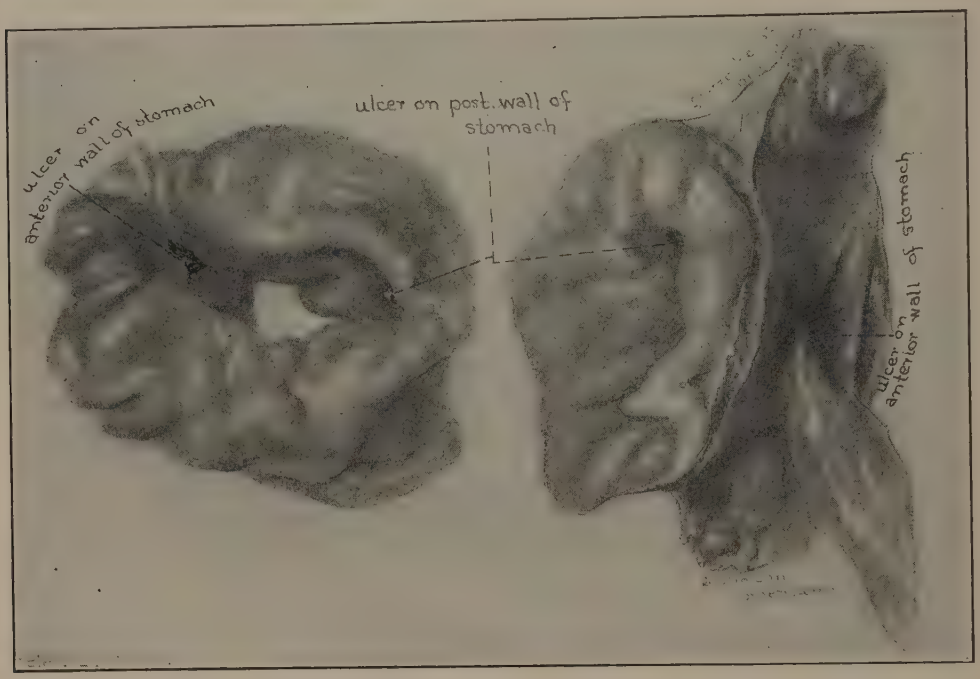


FIG. 90.—SEGMENT OF STOMACH REMOVED BY MID-GASTRIC RESECTION SHOWING "KISSING" ULCERS.
On the anterior wall the ulcer had penetrated through to the peritoneum.

In an operation of this type it is impracticable to leave the mucosa of the stomach out of the grasp of the suture, because of the technical difficulties involved in suturing the posterior wall of the stomach without including the mucosa. Then, too, the extensive blood supply would make the loss of blood too great to attempt a procedure that can well be carried out in a pyloroplasty or in other gastric regions where the incised vessels are small and infrequent. However, it will be noted that, though the suture line of the posterior wall of the repaired stomach is exposed to the gastric lumen, the suture line of the anterior wall is not, because by making no effort to invert the tissues anteriorly the margins of the stumps are gathered together as a ridge which contains the sutures, and this ridge is covered by peritoneum by applying a row of sutures like the outer row on the anterior wall of a gastro-enterostomy.

After a "sleeve" resection it is usually not necessary to do a pyloroplasty, though gastric lavage should be employed at frequent intervals. The oral portion of the stomach naturally should be kept empty as much as possible. The pyloric portion does not need so much assistance as the cardiac part of the stomach that has to empty through the completely sutured circumference. If work can be taken from the cardiac half by removing its contents there will be but little for the pyloric portion to do (Figs. 89, 90).

## HOURGLASS STOMACH

Hourglass stomach results from connective tissue contraction that follows ulcerative or inflammatory processes in the body of the stomach. The diagnosis is made evident by a roentgenologic examination. Surgical treatment of this condition depends upon the extent of the contraction. If the contraction is not marked, a longitudinal incision sutured transversely after the principle of the Heineke-Mikulicz pyloroplasty is satisfactory. Such contractions, however, often recur. If there is healthy tissue along the lesser curvature, and the rest of the gastric circumference at the hourglass contraction consists of scar tissure, the procedure of uniting the two portions of the stomach called "gastro-gastrostomy," by a technic similar to that used in the Finney pyloroplasty, is satisfactory. This is carried out by first uniting the two portions of the stomach posteriorly by a continuous or interrupted row of sutures, and then making a horseshoe incision up one half of the stomach, across the isthmus, and down the other half. The bleeding vessels are caught as they are cut, or else the operation may be done by placing a soft-bladed clamp on each half of the stomach. The use of clamps, however, has its distinct objections, as already discussed, and though the operation may be somewhat more tedious without clamps, the eventual result of having satisfactory hemostasis and the avoidance of additional trauma should be worth while.

If there is marked scar tissue along the whole circumference of the stomach, this affected segment had best be excised in a "sleeve" resection and the wound sutured as described for this operation.

# CHAPTER XIII

## PARTIAL AND TOTAL GASTRECTOMY

### PYLORECTOMY OR PARTIAL GASTRECTOMY

The pyloric portion of the stomach is a very frequent site of pathology. Both peptic ulcers and cancer occur often in this region. Derangement of the mechanism for controlling the exit of food gives early symptoms, and consequently is more likely to be recognized than a lesion at other portions of the stomach where the sphincteric apparatus is not affected. It is important in operations upon the pyloric outlet to provide a free opening. This should be done not only because of the necessity for avoiding possible future contraction and stricture formation, but in order to give the stomach comparative rest by making it easy to expel the gastric contents. It should be borne in mind, too, that the opening at the pyloric end of the stomach should be in a general line with the axis of the peristaltic waves along the lesser curvature, so that the force of the peristalsis will fall directly upon the opening and not against a pocket.

There are many different types of pylorectomy or partial gastrectomy. They depend to some extent upon the amount of stomach that is to be excised. If only the pyloric portion of the stomach is to be removed and a junction can be made without tension between the stump of the stomach and the stump of the duodenum, it is always best to make such an anastomosis, because this allows the stomach to empty in approximately a physiological manner by expelling its contents into the duodenum, the normal mixing chamber for the stomach contents and the bile and pancreatic fluid. If, however, it is impossible to approximate the stump of the stomach to the duodenum without too much tension, other methods must be employed.

We are coming back to the principles established by Billroth in his two methods of resection of the stomach. The Billroth I operation consisted in uniting the stump of the stomach to the stump of the duodenum after pylorectomy. In the Billroth II, when the stump of the stomach could not be brought to the duodenum, both were closed and a posterior gastro-enterostomy was done. A few years ago the Polya operation became very popular, supplanting in many clinics the Billroth II operation, and to some extent the Billroth I.

The principle of the Polya operation is to apply to the stump of the stomach a loop of jejunum. By this means it was argued that the time of the operation was shortened, because instead of suturing the end of the stomach and then doing a gastro-enterostomy on the small remaining portion, where access was difficult, the loop of jejunum was applied directly to the stump of the stomach,

so saving time and enlarging the gastric capacity. In the original Polya, the gastric stump was brought down through an incision in the transverse mesocolon after the manner of a gastro-enterostomy. When this could not be done a loop of jejunum was carried through this mesocolon and sutured to the end of the stomach. Balfour introduced the modification of bringing up the loop of jejunum anteriorly in front of the transverse colon. This is technically less difficult than the posterior Polya, and renders access much easier (Fig. 107).

In the Kocher method of partial gastrectomy the stomach is closed and the end of the duodenum is sutured into an incision made into the posterior wall of the stomach about 1½ inches (3.8 cm.) back of the suture line. Bloodgood, who favors this operation, relieves the tension by dissecting away a good portion of the tissues along the lesser curvature of the stomach, and so overcomes an obvious objection.

Finney, of Baltimore, and Haberer, of Innsbruck, have independently devised a technic of pylorectomy in which, after resection of the pyloric portion of the stomach, the duodenum is thoroughly mobilized and the stump of the stomach is sutured into an incision made along the anterior inner surface of the duodenum.

**Modified Billroth I Partial Gastrectomy.**—According to the original technic of the Billroth I operation, after excision of the pyloric portion of the stomach, union was made between the stump of the duodenum and the greater curvature. The chief objection formerly urged against this operation was that there was supposed to be a peculiar liability for leakage at the triangular point where the line of sutures in the upper portion of the end of the stomach came in contact with the duodenum and the suture line spread out like an inverted Y. At this point leakage frequently occurred. It was doubtless due to the fact that the sutures were too numerous, too tightly tied, and there was not sufficient invagination. This danger is not a serious one if the sutures are properly placed. An inherent objection to the original technic of the Billroth I operation is that suturing the thin wall of a small-caliber intestine such as the duodenum to the thick wall of the stomach necessitated invagination that would tend to occlude the lumen and produce obstruction. Then, too, as the stomach empties chiefly along the lesser curvature, the waves of peristalsis break against the blind pouch at the upper part of the gastric stump and their force is deflected toward the duodenal opening at the greater curvature. In order to obviate these difficulties the following modifications of the Billroth I have been practiced by me with satisfaction.

First of all, the union is made along the lesser curvature. This insures the continuity of the axis of peristalsis. Secondly, an incision is made in the anterior wall of the duodenum for a distance of about an inch or an inch and a half (2.5 or 3.8 cm.). This flares open the duodenum and makes a wide surface for union with the stomach so that the tendency toward constriction at this point is overcome. The technic for pylorectomy according to this procedure is as follows: A good exposure is obtained and the gastrohepatic omentum is opened. Particularly in malignancy as much of the

gastrohepatic omentum is included in the tissue to be resected as possible. The branches of the gastric artery along the lesser curvature are doubly clamped and divided, and those of the pyloric near the first portion of the duodenum are doubly clamped and divided. The hand is inserted in the lesser peritoneal cavity, the stomach is lifted up, the gastrocolic omentum

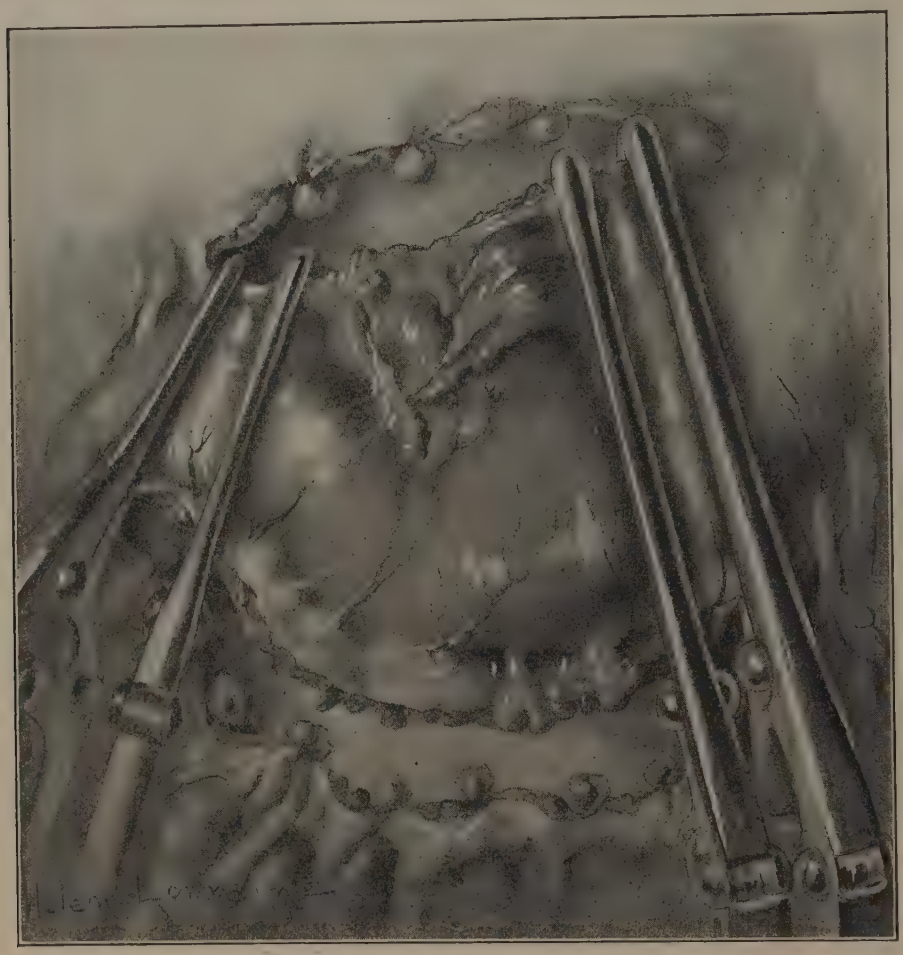

FIG. 91.—PARTIAL GASTRECTOMY OR PYLORECTOMY.

The omental attachments to the stomach have been severed and clamps applied along the lines of proposed excision. The clamps nearest the lesion may be soft-bladed instead of Payr clamps.

incised, and the vessels along the greater curvature are doubly clamped and divided. In this way the pyloric end of the stomach is suspended free from its omental attachments. After packing off the lesser peritoneal cavity the vessels which have been clamped are controlled by transfixing and tying the tissues within the grasp of the forceps with plain catgut in a needle, as has been mentioned under the head of mid-gastric or "sleeve" resection. On the larger vessels two ligatures are tied for safety. A small Payr clamp is placed on the

duodenum close to the pylorus, and another clamp, preferably a soft-bladed forceps is applied close to the Payr clamp (Fig. 91). The tissues posteriorly are particularly well protected and the duodenum is severed with the electric cautery flush with the Payr clamp.

The pyloric end of the stomach is lifted up so as to obtain a good view of the posterior surface. This should be done gradually, however, because

FIG. 92.—THE PYLORIC PORTION OF THE STOMACH HAS BEEN REMOVED AND THE POSTERIOR WALL OF THE STOMACH HAS BEEN SUTURED TO THE POSTERIOR WALL OF THE DUODENUM.
If there is abundant space a continuous suture as shown may be used. Otherwise interrupted mattress sutures should be placed.

if the stomach is full the sudden lifting up of the pyloric end may cause regurgitation of gastric contents into the esophagus and pharynx with aspiration into the larynx. If the stomach is full it would be best to place a Payr clamp on the body of the stomach before the pylorus is severed, though it is of some advantage to inspect the posterior surface before applying this clamp. It all depends upon the amount of contents in the stomach, which

usually is not great. When this Payr clamp is placed on the body of the stomach, at a sufficient distance from the disease, a pair of long soft-bladed forceps is applied close to the Payr clamp and the pyloric portion of the stomach is severed with the electric cautery, cutting flush with the Payr clamp. This leaves two stumps, both included in Payr clamps, and with tissues that are charred flush with the surface of the clamp so no stump projects from the clamp. This portion of the procedure is similar for any

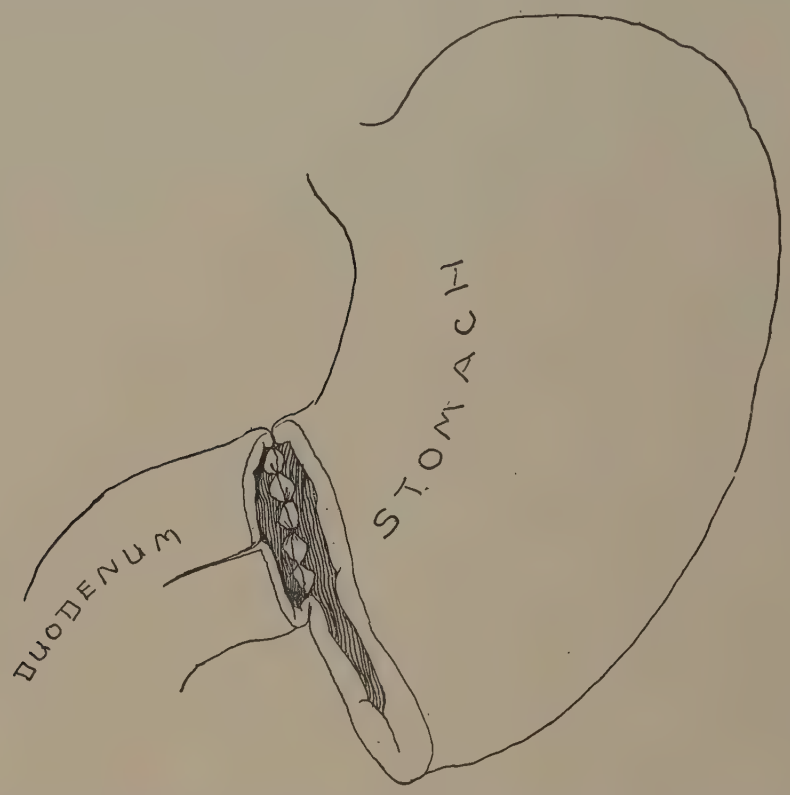


FIG. 93.—DIAGRAM SHOWING THE INCISION INTO THE ANTERIOR WALL OF THE DUODENUM IN ORDER TO FLARE IT OPEN AND PREVENT CONSTRICTION ALONG THE LINE OF SUTURES.

technic of pylorectomy, whether it be the modified Billroth I, the Polya, or the Billroth II.

In the modified Billroth I the stump of the stomach must be capable of being easily approximated to the stump of the duodenum. If this can be done the stomach is brought over to the duodenum and the posterior wall of the stomach is united to the posterior wall of the duodenum with a continuous mattress suture or with a series of interrupted mattress sutures of 00 tanned catgut (Fig. 92). These are applied fairly snugly, but not tight enough to produce necrosis. The ends of the lower suture and of the upper suture are left long to facilitate handling in the later stages of the operation. It will be noted that this is different from the technic in mid-gastric resection in which

the posterior row of superficial sutures is applied as the last stage. In mid-gastric resection, however, the posterior surface of the stomach can be readily exposed by the methods previously mentioned, while in a pylorectomy the peritoneal union of the posterior gastric wall to the duodenum, which is rather

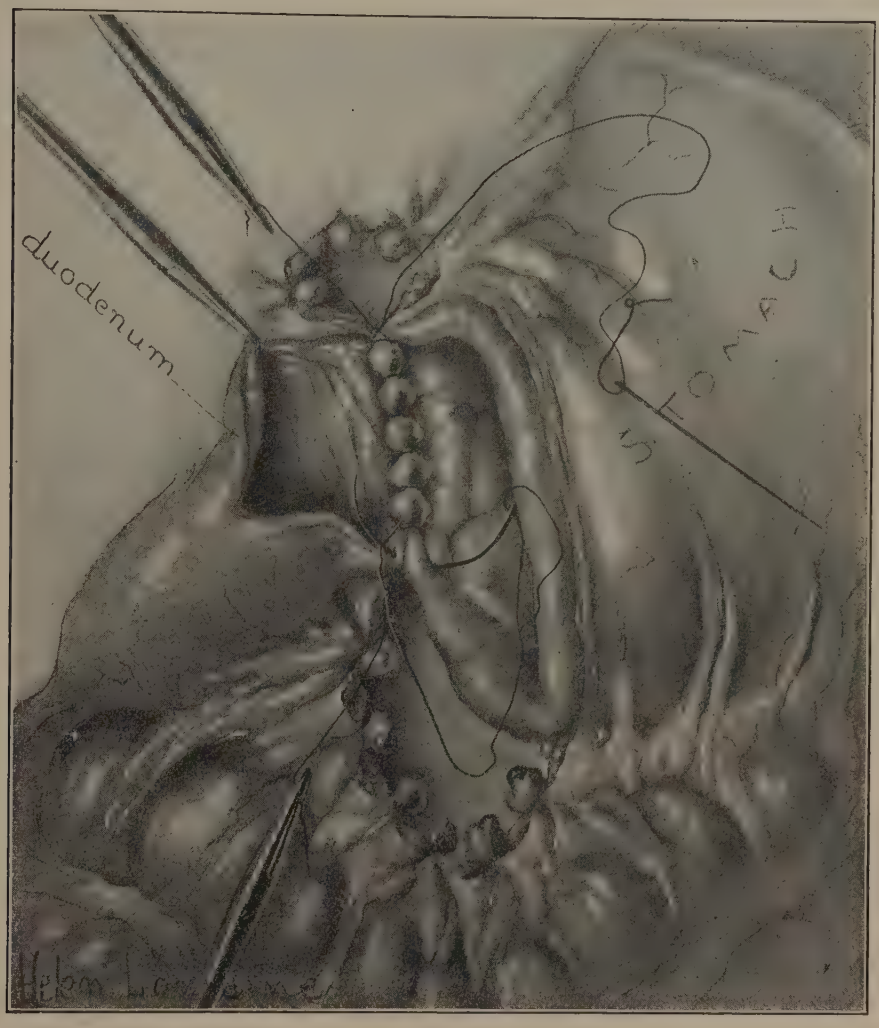


FIG. 94.—THE DUODENUM HAS BEEN FLARED OPEN BY AN INCISION IN ITS ANTERIOR WALL AND THE INNER ROW OF SUTURES IS BEING APPLIED AS A CONTINUOUS LOCKSTITCH, PENETRATING ALL COATS OF THE STOMACH AND DUODENUM.

firmly fixed, is too difficult if postponed until after the internal row of sutures has been placed. In spite of the disadvantages of subsequent manipulations straining the line of sutures, it seems preferable under the circumstances to do this suturing at first. They may be best inserted with a small round curved needle. The Payr clamp on the stomach is removed and Oschner forceps are placed on the crushed margin of the lower portion of the

FIG. 95.—WITH A LARGE STUMP OF THE STOMACH WHICH EVEN A FLARED DUODENUM CANNOT COVER, A SEPARATE LINE OF SUTURES IS APPLIED ANTERIORLY, UNITING THE MARGINS OF THE DUODENUM AND THE STOMACH WITHOUT ANY EFFORT AT INVERSION.
The suture is applied snugly to control bleeding.

stump of the stomach while the upper part is opened and any accumulated fluid in the stomach is removed with a suction apparatus. The Payr clamp on the duodenum is then removed and the duodenal contents are drawn off with a suction apparatus. With a No. 1 tanned catgut suture the upper

FIG. 96.—THE INNER ROW OF SUTURES HAS BEEN COMPLETED ANTERIORLY.
The teat-like projection left at the lower border of the stump of the stomach is invaginated with a purse-string suture as in the technic for pyloroplasty. This suture is then continued over the anterior surface of the stomach as in pyloroplasty, burying the inner row of sutures.

margin of the stomach at the lesser curvature is united to the upper margin of the duodenum. The suture is tied several times on the surface of the mucosa and the end left long. With a continuous lockstitch the posterior wall of the stomach is sutured to the posterior wall of the duodenum (Fig. 94).

When the lower border of the duodenum has been reached an incision of

about an inch and a half (3.8 cm.) is made in the anterior surface of the duodenum, which serves to flare open the duodenum and give a somewhat funnel effect (Fig. 93). This permits a few additional sutures between the posterior wall of the stomach and the posterior wall of the duodenum. This incision sometimes flares open the duodenum sufficiently to enable the whole of the posterior wall of the stomach to be united to the posterior wall of the duodenum. In a large stomach, or if the resection has been moderately

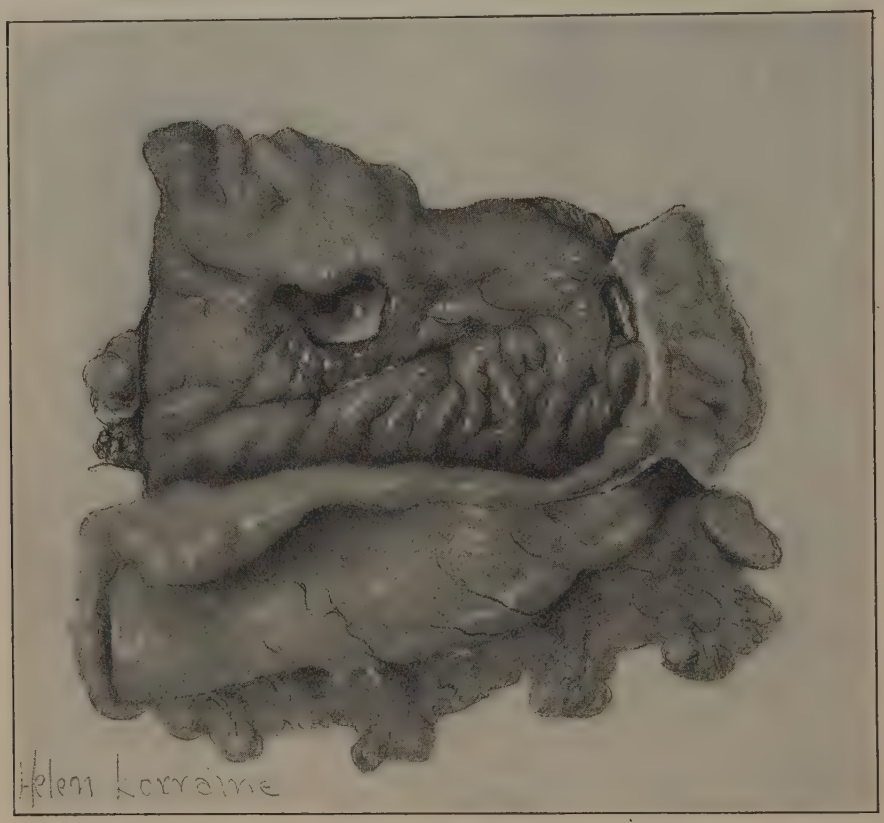


FIG. 97.—SPECIMEN SHOWING MULTIPLE ULCERS OF THE STOMACH, REMOVED BY THE MODIFIED BILLROTH I TECHNIC.

Viewed from behind. A large ulcer in the upper posterior wall, a smaller one in the anterior wall near pylorus.

extensive, there will be still a redundancy in the stump of the stomach (Fig. 94). When, as usually happens, such a redundancy exists, the suturing is carried down after removing the Ochsner clamp that has been placed on this portion of the stomach, suturing the posterior stomach wall to the anterior stomach wall by a continuous lockstitch, and making no effort to invert the tissues. This same suture can be doubled back on itself and then carried anteriorly, uniting the anterior wall of the stomach to the anterior wall of the duodenum. If, however, the tissues are rather thick it would be best to terminate this suture at the lower border of the stomach and use another line

of sutures to join the anterior wall of the stomach to the anterior wall of the duodenum, beginning above and going down as a lockstitch, catching all of the coats of the duodenal and gastric walls (Fig. 95).

The lower portion of the stump of the stomach along the greater curvature is invaginated with a purse-string suture and this suture is continued anteriorly, as in pyloroplasty, as a continuous right-angle suture, with a backstitch at intervals, and buries the internal row of sutures (Fig. 96). It terminates at the lesser curvature. At the lower border of the duodenum a mattress suture

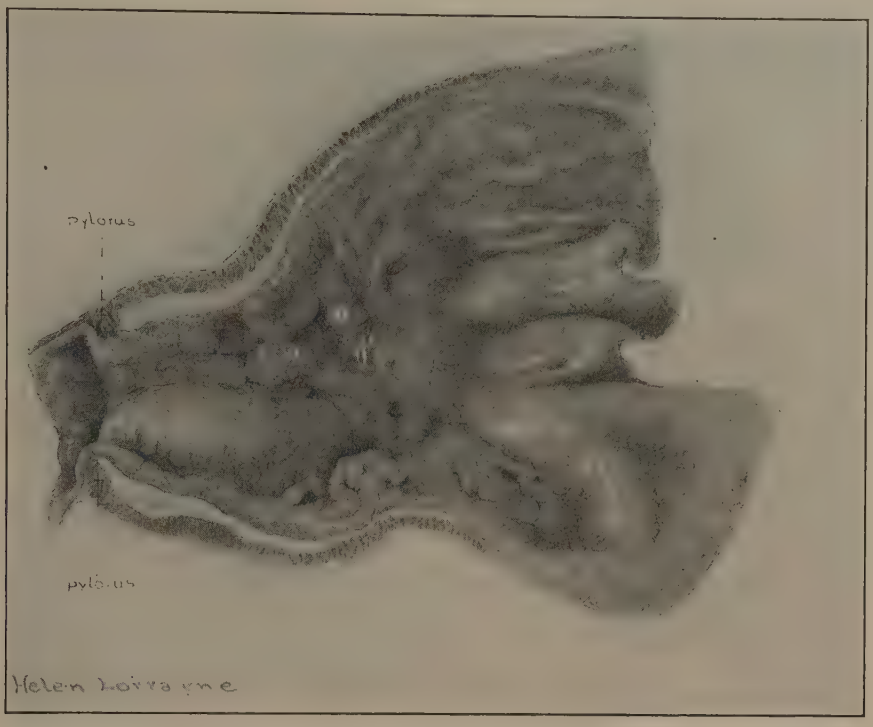


FIG. 98.—SPECIMEN OF CARCINOMA OF THE PYLORIC END OF THE STOMACH REMOVED BY THE MODIFIED BILLROTH I TECHNIC.

Note the extent of the stomach which can be removed by this operation when the patient is thin and the tissues are relaxed. This operation was done under local anesthesia.

is placed still further to infold the tissues and with it is caught some neighboring gastrocolic omentum, which may also be fastened with 00 tanned catgut along the anterior line of sutures, as is done in pyloroplasty. It is probably unnecessary to cover the whole anterior line of sutures with omentum as a routine measure, though if there appears to be any weakness in the sutures or any unusual tension, this can be easily done. At the upper border an additional interrupted mattress suture of 00 tanned catgut is placed to strengthen the union at this point, because it is here that peristalsis is particularly active. Some of the neighboring stumps of gastrohepatic omentum are caught in this suture and tied, or additional sutures may be used to fasten the stumps of the gastrohepatic omentum in this region (Figs. 97-100).

**The Finney-Haberer Partial Gastrectomy.**—In the Finney-Haberer operation the pyloric portion of the stomach is resected as has just been described. The stump of the duodenum, however, is buried by a purse-string suture placed before the Payr clamp is removed. This suture may be of linen or of tanned catgut, and is inserted preferably with a curved needle rather close to the Payr clamp. It is placed as a running suture, first posteriorly and then anteriorly. The Payr clamp is gradually removed and the purse-string suture is tightened as the Payr clamp is withdrawn, while the crushed portion of the bowel is inverted. If there is a considerable amount of fat, it may be better to use a basting stitch instead of the purse-string suture. The basting stitch is applied by catching a bite of tissue (Figs. 104, 105), first on one side of the Payr clamp and then on the other. Traction is made on the two ends of the suture in opposite directions as the Payr clamp is removed. This, which is one of the steps used for the Kerr intestinal resection, automatically inverts the stump of the duodenum. The walls of the duodenum are puckered together as closely as possible and the two ends of the suture tied to each other. After applying the purse-string or the basting suture a second suture, preferably of 00 tanned catgut, is placed burying the original suture, and then a third may also be inserted if it seems advisable. Some adjacent peritoneal covered fat may be caught in the long ends of the last suture and brought over the stump of the duodenum.

FIG. 99.—ROENTGENOGRAM TEN MONTHS AFTER THE MODIFIED BILLROTH I OPERATION.

The function of the stomach appears to be normal.

FIG. 100.—ROENTGENOGRAM FOUR YEARS AND THREE MONTHS AFTER THE MODIFIED BILLROTH I.

In this case the stump of the stomach was small and was united to the duodenum end-to-end without the necessity of flaring open the end of the duodenum by an incision. The function of the stomach is apparently normal.

Either at this stage, or before the resection, the duodenum is thoroughly mobilized down to the level of the lower portion of the head of the pancreas for a distance of about three inches (7.7 cm.) from the closed stump of the duodenum. Finney does this carefully as in his technic for pyloroplasty. The peritoneum along the outer border of the duodenum is divided with knife or scissors, and then the tissues are loosened with dry gauze or with spreading scissors dissection. Of course, injury to the common duct and the hepatic vessels should be avoided, but with ordinary care no such accidents

should happen. There are usually a few bleeding points which are caught and tied. It is important to have no band of tissues holding back the duodenum, and to mobilize the bowel down to the lower level at the head of the pancreas where the duodenum begins to change its direction to cross the spine. A similar incision is made in the peritoneum along the inner border of the duodenum and mobilization with dry gauze or with blunt scissors dissection is done. In this way it will be found that the duodenum can be freed laterally so that it has almost the effect of an attached mesentery, though it is still fixed from above downward.

The stomach is brought over to the surface of the duodenum and, if it is apparent that it can be fastened in this position without too much tension, a row of sutures unites the posterior wall of the stomach just behind the Payr clamp to the anterior surface of the duodenum near its inner border. These sutures may be continuous or interrupted. Usually when the duodenum is well mobilized a continuous right-angle or mattress suture with an occasional backstitch to lock it is satisfactory. Finney uses silk, though there is no reason why tanned catgut cannot be employed for this suture. An incision is made in the duodenum from a point near the stump of the duodenum downward for a distance of about 3 inches (7.7 cm.). The bleeding vessels are clamped with sharp-nosed forceps and the duodenal contents withdrawn with a suction apparatus. The Payr clamp is removed from the stump of the stomach, and beginning at the lower border the posterior wall of the stomach is sutured to the posterior margin of the incision in the duodenum with a continuous lockstitch of No. 1 tanned catgut. If the stump of the stomach exceeds the length of the incision in the duodenum, and the incision in the duodenum has been made to its lower mobilized portion, it is well to catch in the bite of the suture a little more of the stomach than of the duodenum, so as to have somewhat the effect of a gathering suture on the gastric side. When the suture reaches the upper margin of the wound it is continued anteriorly in the same manner, catching a narrow bite of tissue both in the duodenum and in the stomach, and is terminated by tying it to the end of the original knot. Care must be taken not to infold too much tissue at the lower border. An accurate approximation, bringing the peritoneal surfaces well together, is all that is necessary. This inner row of sutures is buried by an anterior row as a continuous right-angle suture with a few backstitches at intervals (Fig. 101). An interrupted mattress suture is placed at the upper and at the lower margins to reinforce these points, but the sutured structures should not be made too bulky at the lower portion for fear of pressing upon the lumen of the duodenum too greatly.

This operation, which was worked out independently by J. M. T. Finney, of Baltimore, and by von Haberer, of Innsbruck, has advantages in establishing a large outlet for the stomach and in uniting the stomach with the duodenum instead of with the jejunum as in the Polya operation. The sutures can undoubtedly be placed with much safety from leakage in this type of operation, because the suturing resembles very much that in gastroenterostomy.

In my own experience the technical effect of this operation is very

satisfactory. There is, however, some objection in the matter of the stomach emptying satisfactorily. The incision in the duodenum puts out of commission the circular fibers and so prevents peristalsis that is dependent chiefly upon the circular fibers in this segment of the duodenum. The duodenum,

FIG. 101.—THE FINNEY-HABERER PYLORECTOMY, IN WHICH THE STUMP OF THE STOMACH IS IMPLANTED INTO THE SIDE OF THE DUODENUM.

The operation has been almost completed. The outer row of sutures is being applied anteriorly.

while mobilized from side-to-side, is comparatively fixed from above downward, and it is readily seen that the stump of the stomach is fixed at its upper and lower borders by the duodenum to which it is attached. When

the stump of the stomach is sutured to the jejunum, which has a mobile mesentery, this segment of jejunum can be folded to some extent from above downward, and the outlet of the stomach can be closed as a kind of sphincter. But with the suturing of the stump of the stomach to the side of the duodenum there is left a roughly triangular area in which the incised duodenum cannot well empty itself because of the injury to its circular fibers and the end of the stomach cannot satisfactorily contract, because it has been sutured above and below to the duodenum which remains fixed in this direction. It may be that I sutured too abundantly along the greater curvature of the stomach and so obstructed by inverting an unnecessary amount of tissue, but in one patient in whom this operation was done, after some irregular emptying over a period of about two weeks and when the patient was losing ground, a posterior gastro-enterostomy was necessary, after which he made a satisfactory recovery (Fig. 102). In another patient in whom I did the Finney-Haberer operation there was never any trouble about emptying, and even the day following operation gastric lavage brought away only three or four ounces of retained stomach contents (Fig. 103).

FIG. 102.—ROENTGENOGRAM OF THE STOMACH OF PATIENT MENTIONED IN THE TEXT IN WHOM A PYLORECTOMY WAS DONE ON MAY 2, 1924, FOLLOWED BY A GASTRO-ENTEROSTOMY 13 DAYS LATER.

This roentgenogram was taken about ten months after the gastro-enterostomy. The stomach is emptying through both the anastomoses to the duodenum and to the jejunum. The patient is symptom-free.

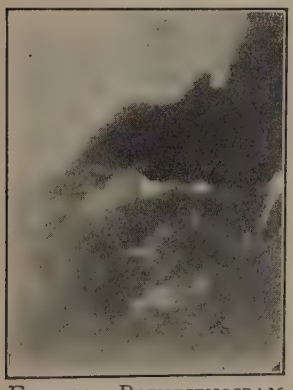

FIG. 103.—ROENTGENOGRAM SIX MONTHS AFTER A FINNEY-HABERER PYLORECTOMY.

The stomach is emptying normally and the patient is symptom-free.

If the stump of the stomach can be brought over to the duodenum I believe that the modified Billroth I operation, which has been described, will be probably more satisfactory than the end-to-side union; though the Finney-Haberer operation, so far as emptying the stomach contents into its normal receptacle is concerned, has a distinct advantage over the Polya operation. Either of these procedures seems better than the Kocher operation, in which the stomach is closed, and the stump of the duodenum united to the stomach by an incision in the posterior gastric wall.

**The Polya Partial Gastrectomy.**—If too much of the stomach has been removed to permit approximation of the stomach to the duodenum without tension some other method of union with the intestine must be employed

(Figs. 104-114). In the original method of Polya the jejunum was united to the stump of the stomach through an opening in the transverse mesocolon. After resection of the pyloric portion, as has been described, and when it is

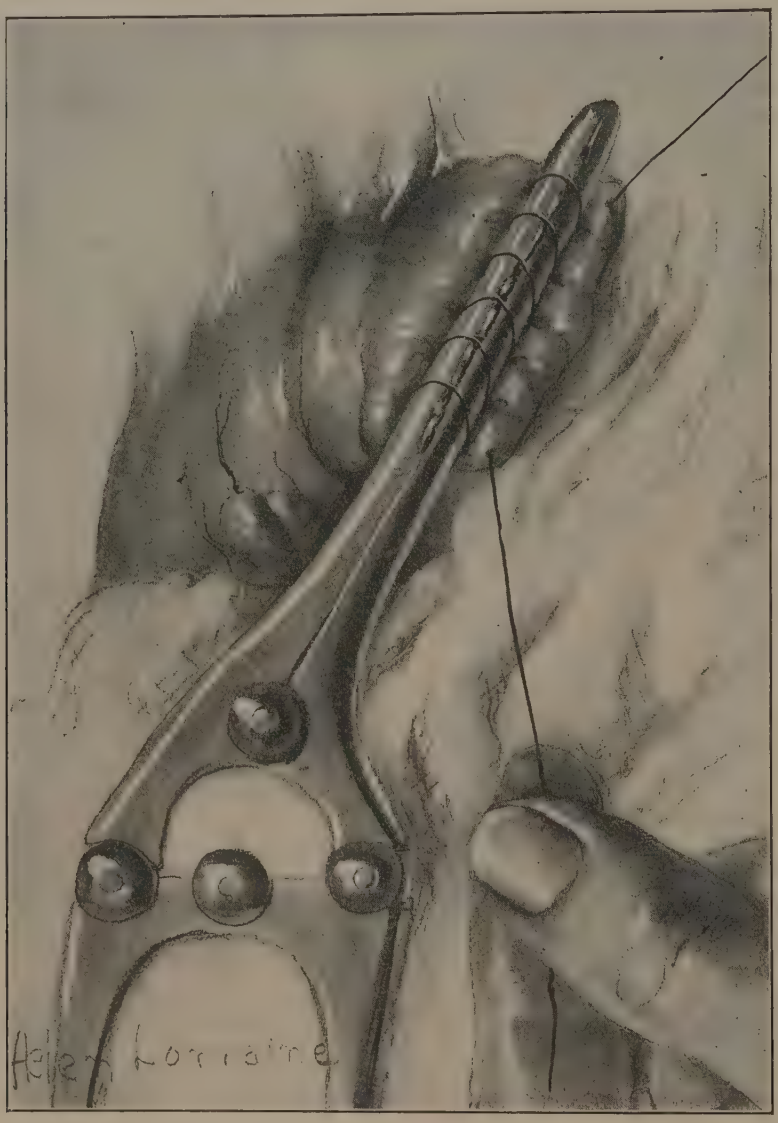

FIG. 104.—THE PYLORIC PORTION OF THE STOMACH HAS BEEN SEVERED FROM THE DUODENUM AND A BASTING STITCH APPLIED OVER THE PAYR CLAMP ON THE STUMP OF THE DUODENUM.

found impossible to unite the stomach to the duodenum, the transverse colon is lifted up as in a gastro-enterostomy and a liberal incision is made about the middle of the transverse mesocolon or in such a position that will render the stump of the stomach most accessible. The stump of the stomach with the attached Payr clamp is drawn down through the opening in the meso-

colon, if this can be done without too much tension; or it would be better to follow the technic of Devine in this respect and, in the first instance, apply the Payr clamp to the stomach through an incision in the mesocolon. A loop of jejunum is selected. The loop should begin about 4 or 5 inches (10.2 or 12.7 cm.) from the origin of the jejunum so as to allow for some retraction of the stomach. The jejunal loop is clamped with long soft-bladed forceps which can cover a segment equal in length to the width of the stump of the stomach. The posterior wall of the stump of the stomach is sutured to the margin of the loop of jejunum, applied so that the oral end of the loop is at

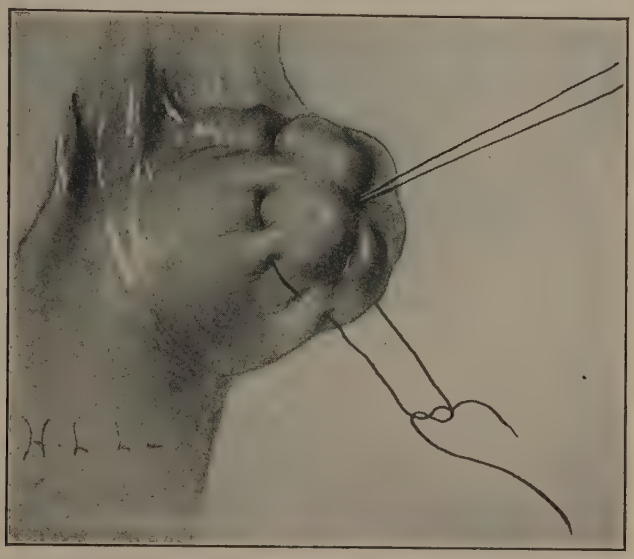

FIG. 105.—THE CLAMP HAS BEEN REMOVED AND THE TISSUES WHICH HAVE BEEN FOLDED IN BY THE BASTING STITCH ARE GATHERED UP TOWARD THE CENTER AND THE TWO ENDS OF THE BASTING STITCH ARE TIED TOGETHER.

Instead of applying the basting stitch as shown in the preceding figure, a purse-string suture may be used which continues around the circumference of the intestine to its original starting point, whereas the basting stitch takes a bite first on one side of the clamp and then on the other. After this purse-string suture is taken, a second purse-string suture is placed to bury the stump still further.

the lesser border of the stomach. This enables the duodenal contents to enter at the upper margin of the stomach and to protect the jejunal mucosa from the action of the gastric juice. The suture material may be of 00 tanned catgut inserted as a continuous right-angle suture, as in gastro-enterostomy. After this has been applied and the tissues have been packed off, a soft-bladed clamp may be placed on the stomach, or the suturing may be done without the clamp. A longitudinal incision in the jejunum is made not quite equal to the stump of the stomach. After removing the Payr clamp, a continuous lockstitch of No. 1 tanned catgut is snugly applied. This suture begins at the lesser curvature of the stomach, and unites the posterior wall of the stump of the stomach to the posterior margin of the wound in the jejunum. When the greater curvature of the stomach is reached

the suture is continued anteriorly, catching a small bite of tissue in its grasp, and uniting the anterior margin of the wound in the stomach to the anterior margin of the wound in the jejunum. The suture is tied to its original end. The first row of sutures is then continued anteriorly as in gastro-enterostomy and tied to the original end, burying the inner row. An additional stitch is placed at each angle of the wound. A few interrupted sutures of fine tanned catgut fasten the stomach to the rent in the transverse mesocolon.

The original technic of the Polya operation has been advantageously modified by Donald Balfour, who brings up the jejunum anteriorly over the

FIG. 106.—THE SECOND PURSE-STRING SUTURE HAS BEEN PLACED AND TIED AND SOME ADJACENT TAGS OF PERITONEAL COVERED FAT FROM THE GASTROCOLIC OR THE GASTROHEPATIC OMENTUM ARE SUTURED OVER THE STUMP OF THE DUODENUM.

The technic shown in this and the two preceding figures is practically the same as the technic in the Finney-Haberer pylorectomy and in the Billroth II type of partial gastrectomy.

transverse colon (Fig. 107). This modified technic permits a more extensive resection and an easier application of the sutures. After an extensive resection it is often impossible to bring down the stump of the stomach through an incision in the mesocolon without too much tension. A loop of jejunum is selected so that its oral portion will be about 8 to 12 inches (20.4 to 30.5 cm.) from the beginning of the jejunum. This depends upon the mobility of the tissues, upon the amount of stomach left after resection, and upon the quantity of fat in the transverse mesocolon and in the omentum. In cases with considerable fat a loop of jejunum would doubtless have to be selected at a further distance than 12 inches (30.5 cm.) from its origin. The jejunal loop is brought up in front of the colon and sutured to the stump of the stomach in the same way as in the posterior Polya operation. The oral

portion of the loop is applied at the lesser curvature and the jejunum is united to the posterior wall of the stomach with a continuous suture (Fig. 108). After this has been applied, and with the jejunum clamped if necessary, soft-bladed forceps may be placed on the stomach back of the Payr clamp. An incision is made in the jejunum, the Payr clamp is removed from the stomach, and the posterior wall of the stomach is united to the posterior margin of the wound in the jejunum with a continuous lockstitch of No. 1 tanned catgut (Fig. 109). This is continued anteriorly and tied to its original

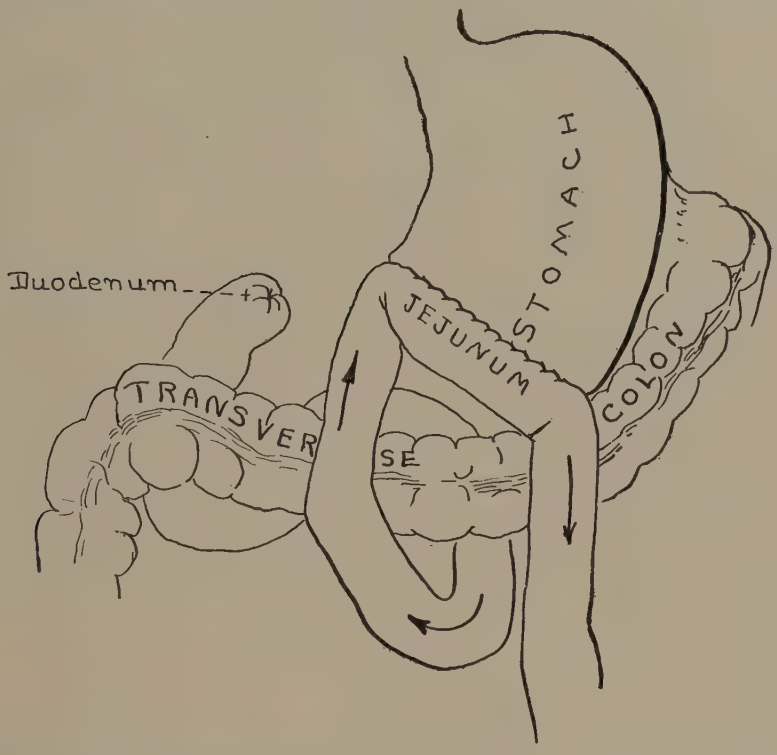


FIG. 107.—DIAGRAM SHOWING ANTERIOR POLYA OPERATION, AS MODIFIED BY BALFOUR.

end. As many large vessels are severed, particular care must be taken with this suture at the greater and lesser curvatures where the largest vessels are, and it is well to take two stitches in the same place in the very vascular regions. At the lesser curvature a mattress suture of 00 tanned catgut is placed and the stumps of the gastrohepatic omentum which have been previously ligated are brought over and sutured in this region. An additional suture is also placed at the greater curvature of the stomach (Fig. 110).

This operation permits a larger proportion of the stomach to be removed than the posterior Polya, and renders the suturing more accessible. It leaves, however, crossing the transverse colon two long limbs of jejunum which may be a potential field for obstruction. It is doubtless safer to do a small entero-anastomosis between the limbs of the jejunal loop just below the transverse

colon, as mentioned in describing anterior gastro-enterostomy. This can be readily accomplished. After uniting the limbs at this point with a continuous suture of 00 tanned catgut, they are incised for an inch (2.5 cm.) and sutured as in posterior gastro-enterostomy, with or without clamps, uniting the pos-

FIG. 108.—ANTERIOR POLYA OPERATION.

A proper loop of jejunum is selected, brought up in front of the transverse colon, and sutured with a continuous right-angle suture to the posterior wall of the stomach near the Payr clamp.

terior margin of the incision in one limb of the jejunum to the posterior margin of the incision in the other, and, continuing the suture anteriorly, tying it to the original end. This inner row of sutures is buried by the original row carried anteriorly as a continuous right-angle or mattress stitch. This entero-anastomosis will prevent a vicious circle or the damming back of the duodenal contents, which is a serious complication.

It may be objected to the entero-anastomosis that it diverts from the site of the union of stomach and bowel the duodenal contents which may protect the mucosa of the jejunum from the action of the acid gastric juice and so

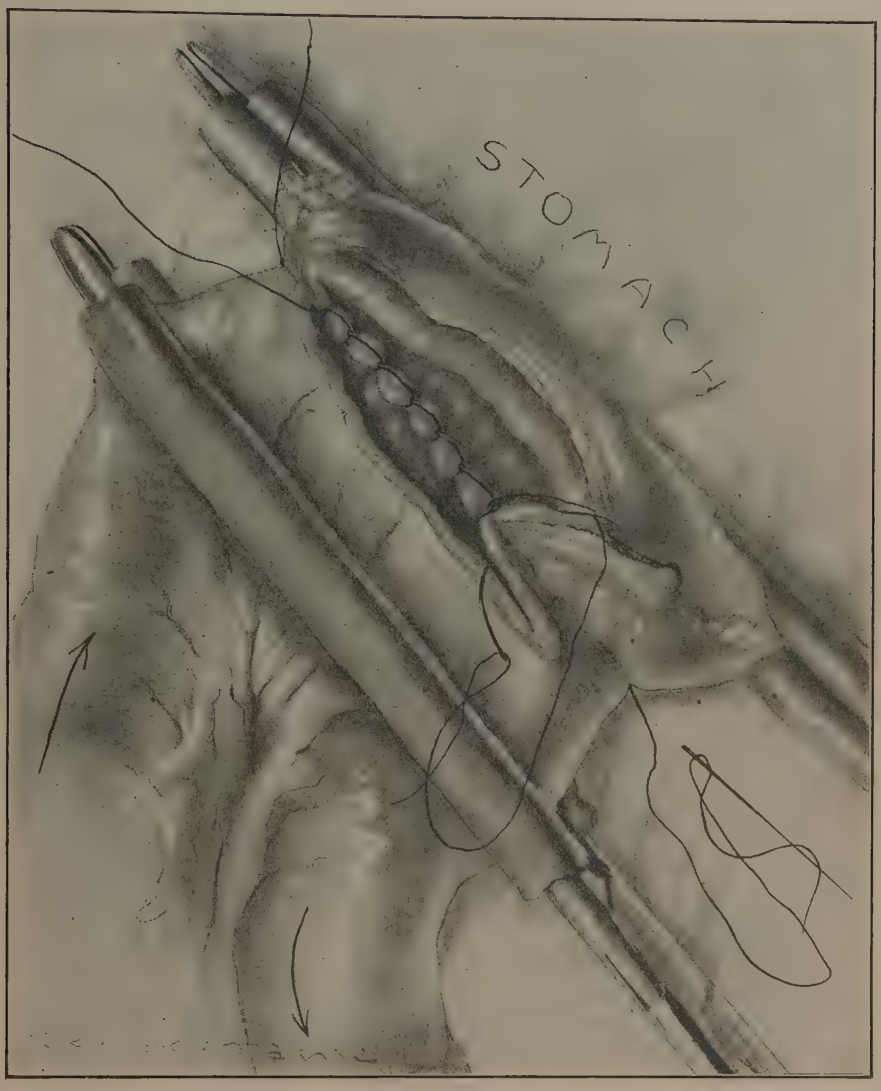


FIG. 109.—THE FIRST ROW OF SUTURES IS TEMPORARILY LAID ASIDE, A SOFT-BLADED CLAMP APPLIED TO THE STOMACH, AND THE PAYR CLAMP IS REMOVED.

The posterior wall of the stump of the stomach is sutured to the posterior margin of the incision in the jejunum with a continuous lockstitch of No. 1 tanned catgut. This suture is carried anteriorly as a continuous lockstitch and tied to its original end, and the outer row of sutures is taken up and completed as in gastro-enterostomy.

prevent jejunal ulcer. A short incision, an inch (2.5 cm.) long, however, will doubtless not drain all of the duodenal contents unless there is marked obstruction above. As the opening is at a right angle to the axis of the peristalsis of the jejunum doubtless some of the duodenal contents will

still be carried to the oral limb of the jejunum that is anastomosed to the stomach and will afford sufficient alkaline material to give a measure of protection. This, of course, is quite different from the "Y" gastro-enterostomy in which all of the duodenal contents are necessarily diverted from the gastric

FIG. 110.—ROENTGENOGRAM FOUR YEARS AFTER ANTERIOR POLYA OPERATION. Peristalsis and the function of the stomach seem normal.

anastomosis. Besides, in a partial gastrectomy usually much of the acid-secreting portion of the stomach is removed.

**Partial Gastrectomy Following a Previous Gastro-enterostomy.**—Occasionally it becomes necessary to follow a gastro-enterostomy with a subsequent resection of the pyloric portion of the stomach. This may be due to the fact that the gastro-enterostomy was done with a lesion in the

pylorus showing too much inflammation to permit a safe resection. The tissues may improve but not heal entirely. Then, too, with patients in a desperate condition it is not wise to do any more than is necessary to save life. When there is complete occlusion of the pylorus from scar tissue usually gastro-enterostomy is a most satisfactory operation and is all that is necessary to be done, but there are occasionally instances in which the conditions are such that it is practically impossible to differentiate between cancer and peptic ulcer with inflammatory exudate. If it is cancer it may appear inoperable and yet after the rest afforded by gastro-enterostomy much surrounding exudate due to accompanying inflammation may be absorbed and render the case operable.

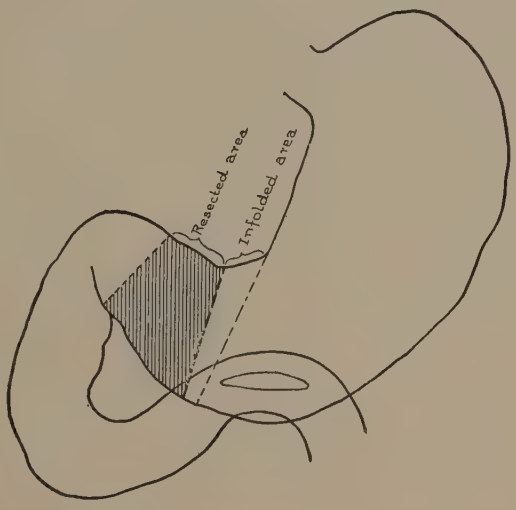


FIG. 111.—DIAGRAM SHOWING LINES OF RESECTION IN A PYLORECTOMY DONE SOME TIME SUBSEQUENT TO A POSTERIOR GASTRO-ENTEROSTOMY.

Cases in which the gastro-enterostomy is intended as the first stage of a pylorectomy, because at that time the patient was too ill to stand a pylorectomy, are simpler, for the gastro-enterostomy was done with a view to the subsequent excision of the pyloric portion of the stomach. When gastro-enterostomy was performed with the intention of its being the sole operative therapy and the conditions change so that pylorectomy is later advisable, the situation is often more difficult because the gastro-enterostomy was placed without regard to the subsequent removal of the pyloric portion of the stomach. It may have been placed so far away as to leave a marked pouch at the distal stump of the stomach unless an unnecessary amount of healthy tissue is resected. This, of course, is a minor difficulty, but a greater one is when the gastro-enterostomy is so close to the pyloric end of the stomach that a pylorectomy and suturing the stump of the stomach cannot be done without infringing upon the region of the gastro-enterostomy. Not infrequently, too, such a pylorectomy is followed by unsatisfactory emptying of the stomach.

This may be better understood by reference to the physiology of the stomach and recalling the fact that the axis of peristalsis is chiefly along the lesser curvature and that peristaltic waves apparently originate about the middle of the body of the stomach and become stronger and deeper as they reach the pylorus. It can be readily seen, then, that if only a part of the pyloric portion of the stomach is resected the remaining stump will be strongly affected by peristalsis, so that food will be carried toward the blind pouch.

If, however, about half of the stomach is resected, most of the stomach that is strongly affected by peristaltic waves has been removed, so that the cardiac portion, in which there are little or no peristaltic waves, remains and is emptied by tonic contraction as described in the chapter on physiology. Thus the mechanical conditions involving the motility of the stomach, when only a small portion of the pyloric end has been removed and when all of it and part of the body have been excised, are quite different. When much of the pyloric portion is left the food will be propelled along the lesser curvature into a blind culdesac and, if the preceding gastro-enterostomy has been done about the middle of the stomach, there may be difficulty in emptying. The conditions are somewhat different from gastro-enterostomy with stenosis of the pylorus, because with pyloric stenosis the adjoining portion of the stomach has doubtless been affected by the pathology that induced the stenosis and the stomach has gradually dilated and accommodated itself.

FIG. 112.—THE LESSER CURVATURE OF THE STOMACH IS FOLDED IN, SO THAT IT DIRECTS THE CURRENT OF FOOD TOWARD THE STOMA OF THE GASTRO-ENTEROSTOMY.

When half or more of the stomach has been excised, the contraction of the remaining cardiac portion is tonic. There are no definite waves of peristalsis, and there is no effort to force food in any particular current. It is as though an elastic rubber bag were punctured. In such instances an opening along the greater curvature of the stomach will give satisfactory results.

When the stomach remaining after a pylorectomy includes a considerable part of the pyloric portion, and there has been a previous gastro-enterostomy, and it is not desired to sacrifice an undue amount of the stomach, the lesser curvature should be turned down by a series of sutures. In this way the lesser curvature is bent so as to point in the direction of the gastro-enterostomy stoma, and food propelled by the peristaltic waves is thus directed toward the stoma (Figs. 111, 112).

**The Modified Billroth II Partial Gastrectomy.**—The Polya operation, particularly the anterior Polya as modified by Balfour, can be done after a limited or an extensive resection. The objections to this operation have already been pointed out. Though there are doubtless instances in which it is indicated, when union of the stump of the stomach to the duodenum is impossible a modification of the Billroth II, sometimes called the Hofmeister operation, seems more logical and more apt to give satisfactory immediate and late results than the Polya. The original Billroth II operation consists in a partial resection, closure of the stump of the stomach and

the duodenum, and then a posterior gastro-enterostomy to the remaining portion of the stomach.

In the modified Billroth II the stump of the stomach in the grasp of a large Payr clamp is gradually released from the clamp, which is transferred to the lower portion of the crushed margin of the stomach; or the Payr clamp may be entirely removed and the lower portion of the crushed margin caught with a series of Ochsner or pedicle forceps. As has already been pointed out, it is

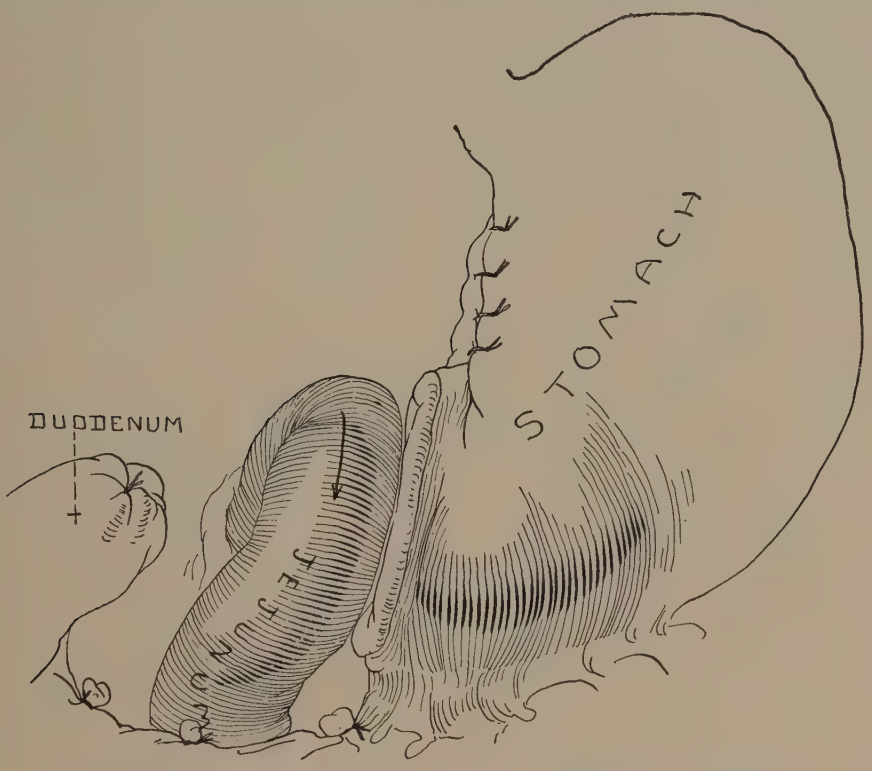


FIG. 113.—THE MODIFIED BILLROTH II OR HOFMEISTER OPERATION.
The upper portion of the stump of the stomach is closed with sutures and the lower portion is united to the jejunum after the manner of a gastro-enterostomy.

unnecessary to cut away the ribbon of tissue crushed by the Payr clamp. A continuous suture of No. 1 tanned catgut is begun at the lesser curvature. It brings the tissues snugly together without any effort at inversion. It is continued to a point about 2 inches above the greater curvature of the stomach and tied in several knots. A second row of sutures of 00 tanned catgut, beginning at the upper angle, inverts the first row of sutures and is terminated in a similar manner about 2 inches above the greater curvature. In this way the upper portion of the stump of the stomach is securely sutured and a snout-like process is left along the greater curvature (Figs. 113, 114).

It must again be recalled that peristaltic conditions are different in the cardiac portion of the stomach left after an extensive gastric resection from

what they are after a limited pylorectomy, because the remaining cardiac portion after an extensive resection is not subject to peristaltic waves and so an outlet along the greater curvature is not objectionable; whereas after a limited resection, with much of the stomach actively affected by peristaltic waves left, the exit for food should be along the lesser curvature.

This protuberance left along the greater curvature is utilized as a stoma for gastro-enterostomy, being brought through an opening in the transverse mesocolon, and a gastro-enterostomy is done connecting the stomach and the jejunum. The jejunum should also be applied over about an inch of the stump of the stomach which has been folded in by the sutures. If it is difficult to deliver the lower part of the stump of the stomach through the rent in the transverse mesocolon the loop of the jejunum is carried through the mesocolon and then sutured to the stump of the stomach. In order to avoid too much tension it may be necessary to use a segment of jejunum that begins somewhat farther down from the origin of the jejunum than would a loop selected for an ordinary gastro-enterostomy. This feature should be scrutinized after the operation is completed, and if the loop appears too long and there is a likelihood of a kink or obstruction, a short entero-anastomosis about an inch in length may be done as described for the Polya operation.

FIG. 114.—THE MODIFIED BILLROTH II OR HOFMEISTER OPERATION COMPLETED.

The jejunum is brought partly over the suture line in the upper part of the stump of the stomach.

The suturing of the jejunum to the lower portion of the stump of the stomach is done by approximating the oral end of the jejunal loop to the upper part of the stoma in the stomach and uniting this loop to the posterior wall of the stomach with a continuous right-angle suture of 00 tanned catgut, taking at intervals a backstitch. After this has been applied an incision is made in the jejunum opposite the opening in the stomach. This is done after placing a soft-bladed clamp on the jejunum or a short incision may be made as described in gastro-enterostomy without clamps, the bleeding vessels being caught, and the incision extended until it is about 2 inches (5 cm.) long. The Ochsner or other clamp that occludes the lower 2 inches (5 cm.) of the stump of the stomach which has not been sutured is removed and the crushed band of tissue is gently separated. The gas and liquid contents of the stomach are removed with a suction apparatus. This is probably better than applying a clamp to the stomach, though a soft clamp may be placed

if desired. The posterior margin of the opening in the stomach is then sutured to the posterior margin of the wound in the jejunum with a continuous lockstitch of No. 1 tanned catgut beginning at the upper portion of the wound. The suture is carried to the greater curvature and continued around the anterior surface of the wound after the manner of a posterior gastro-enterostomy and tied to its original end. This inner layer of sutures is then buried anteriorly by taking up the original row that was applied posteriorly as a right-angle suture and carrying it in front. In addition a few interrupted mattress sutures of 00 tanned catgut should anchor the jejunum about an inch over the sutured portion of the stump of the stomach just above the stoma, and at the greater curvature a mattress suture is applied. The stoma is brought through the rent in the mesocolon if it has not already been delivered, and interrupted sutures of catgut are placed between the margin of the opening in the mesocolon and the stomach about a half inch (1.3 cm.) to an inch (2.5 cm.) above the suture line.

## TOTAL GASTRECTOMY

Total gastrectomy has been done a few times, though the indications for this operation are of necessity very limited. Such an operation would probably be for cancer, and if the cancer is sufficiently advanced to demand total excision of the stomach it has usually invaded the surrounding tissues to such an extent that there would be no hope of cure by even such a radical operation as removal of the stomach. In linitis plastica, or leather-bottle stomach, which many authorities think is always cancerous, such an operation may sometimes be indicated.

The exposure should be ample and the incision be made a little to the left of the midline, from the ensiform cartilage to below the navel. If necessary to secure a better view, the lower end of the incision may be flared open by extending it outward and downward as in Bevan's incision. The lower abdominal contents should be well packed off to prevent soiling. The vessels along the lesser curvature are doubly clamped, divided and tied, the stomach is lifted up, and the vessels along the greater curvature are doubly clamped, divided and tied. The vessels to the spleen are clamped, divided and tied, and the stomach is thoroughly mobilized so that it hangs only by its attachments to the esophagus and to the duodenum. The esophagus is freed so that it can be delivered as much as possible into the peritoneal cavity. If the pathologic conditions will permit, a small portion of the cardiac part of the stomach left attached to the esophagus will make the operation less difficult, but of course such an operation cannot be called a complete gastrectomy.

The lesser peritoneal cavity is packed off with hot moist gauze. The duodenum close to the pylorus is clamped with a small Payr clamp and another clamp, preferably soft-bladed to avoid crushing through the affected stomach tissue, is placed on the pylorus close to the Payr clamp. With the electric

cautery the duodenum is divided flush with the surface of the Payr clamp. The stomach is turned up gently so as to prevent forcible regurgitation of the stomach contents into the pharynx and larynx. By gentle traction on the lesser curvature the esophagus is brought down as far as possible and exposed. The tissue beneath the esophagus should be well protected with moist gauze. A clamp is placed on the cardiac portion of the stomach close to the esophagus and the esophagus is divided. If enough of the esophagus can be brought down to be clamped with a soft-bladed clamp, this may be done, but such a condition would be rather unusual and it is doubtful whether the trauma of the clamp on the soft tissue of the esophagus would not do more harm than the application of the clamp would do good. If the stump of the esophagus seems to be short, it would be wise to apply several mattress sutures as tractor sutures, preferably placing them and leaving them untied at intervals around the esophagus. Before the esophagus is divided a loop of jejunum is selected so that it can be brought over the transverse colon and readily approximated to the stump of the esophagus without tension. This should be as close to the origin of the jejunum as possible. If sufficient of the esophageal tissue can be brought down, a posterior row of sutures is applied uniting the loop of jejunum as in a posterior gastro-enterostomy to the posterior wall of the esophagus with a continuous right-angle suture of 00 tanned catgut, taking a backstitch at intervals. After the posterior suture has been completed an incision from 1½ to 2 inches (4 to 5 cm.) long is made into the jejunum and the posterior margin of the wound in the jejunum is united to the posterior margin of the stump of the esophagus with a continuous lockstitch of No. 1 tanned catgut. This is continued around the whole surface, taking as small a bite in the margin of the esophagus as possible, and drawing the suture snugly enough to secure hemostasis. The suture is tied to its original end. The outer row of sutures is continued anteriorly, burying the inner row.

In some instances 2 inches (5 cm.) or more of the esophagus may be brought down into the peritoneal cavity below the diaphragm, and of course the more the esophagus can be brought down the simpler the operation will be. If the stump is short it may not be possible to carry out the technic of a double row of sutures. A Murphy button has been used, placing half of the button in the lower end of the esophagus and securing it with a purse-string suture, and the other half through a small incision in the jejunum. The Murphy button in this region, however, would appear to be accompanied by considerable risk. The esophagus is rather more friable than the jejunum, and it is possible that the button might cut through too early. Besides this objection, a large foreign body of this nature might fall into the oral end of the jejunal loop. It would seem more desirable to depend upon sutures, even though it makes the operation somewhat more tedious. The line of sutures may be reinforced by stitching over it tags of peritoneal covered fat in the neighborhood. If adjacent peritoneal covered fat is not available a portion of the great omentum can be brought up and sutured.

On account of the constant motion in the diaphragm and the alternating

pressure and traction in this region, care should be used to make the line of sutures safe, for if leakage occurs a fatal result would be most probable. It would be safer, even though the sutures appeared satisfactory, to reinforce them with peritoneal covered fat in the manner indicated. It is also doubtless better to make an entero-anastomosis between the two limbs of jejunum united to the esophagus at the point where these limbs cross the transverse colon.

Finney and Reinhoff reported at the Surgical Section of the American Medical Association in May, 1925, several cases of total gastrectomy in which the esophagus was united to the duodenum.

The after-treatment of such cases should be governed by the knowledge of the absence of the stomach and the limited capacity of the jejunum as compared with the stomach. Only small amounts of water should be given at first, and later frequent feedings of liquid food, either predigested or of such a nature that would ordinarily require no digestion from the stomach.

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## CHAPTER XIV

## THE DUODENUM

**Ulcers of the Duodenum.**—Duodenal peptic ulcers are found most frequently in the first portion of the duodenum, in the anterior wall, and are treated somewhat as gastric peptic ulcers would be when located near the pylorus. A pyloroplasty or a gastro-enterostomy is indicated in many of these cases. Sometimes resection of the pyloric end of the stomach is done. When, however, the ulcer is in the duodenum an inch or more from the pylorus, different methods of procedure must be adopted, and the ulcer may be considered as a pure duodenal lesion without the necessity of always including the stomach in the surgical therapy of this lesion.

If the ulcer is reasonably accessible in the anterior wall of the duodenum, and more than an inch from the pylorus, it may be excised by a transverse elliptical incision, as has been practiced by E. S. Judd, and sutured transversely, the first row of sutures bringing all the coats of the duodenum in apposition, and the second row burying the first. The sutures are preferably of tanned catgut. For additional security a neighboring tag of peritoneal covered fat may be brought over the line of sutures and fastened with a few interrupted stitches of catgut.

Ulcers further down in the duodenum are quite rare, but occur. When in the last half of the duodenum they are practically inaccessible for direct surgical attack. In such a case the indicated procedure would be a posterior gastro-enterostomy with exclusion of the pylorus. In order to exclude the pylorus permanently for this kind of ulcer it would doubtless be best to follow the procedure advocated by R. A. Barr, of Nashville, and divide the pyloric end of the stomach by first incising the muscular coat down to the mucous membrane, doubly ligating and dividing the mucous membrane, and then infolding each stump by pushing in the mucosa and suturing the muscular and peritoneal coats over it. This would give the ulcer comparative rest by preventing passage of food over it and would also maintain a high alkalinity of the duodenal contents that came in contact with the ulcer.

Extensive duodenal ulcers, accompanied by a considerable amount of inflammatory exudate, do not admit of excision, and are treated in a somewhat similar manner, though if near the pylorus occlusion of the pylorus by a stout kangaroo tendon is usually satisfactory, as has been pointed out before. A stout kangaroo tendon tied tightly enough to occlude but not to produce necrosis may, in the presence of inflammation, produce a prolonged if not a permanent occlusion, and so give rest to the tissues, permitting the ulcer to heal. When such an ulcer heals, the resulting scar often causes stenosis. Cases in which this procedure has been done seem to show that pyloric

ligation under these circumstances is different from ligation when there is no inflammatory reaction in the region in which the kangaroo tendon has been applied.

H. B. Devine, of Melbourne, Australia, has advocated a treatment of duodenal ulcers based upon the physiology of the sympathetic nervous system on which much work has recently been done by Pavlov and by John Hunter, of Sydney. Hunter has shown that all muscle, including voluntary muscle, has a sympathetic nervous supply as well as a direct motor nerve supply, and that it is the nerves of the sympathetic that preserve a normal posture without undue muscular fatigue. Devine believes that there are three ulcer stages. In the first of these stages the stomach is irritable and spastic, and empties rapidly. It is this condition, according to Devine, which seems sometimes actually to precede ulcer formation.

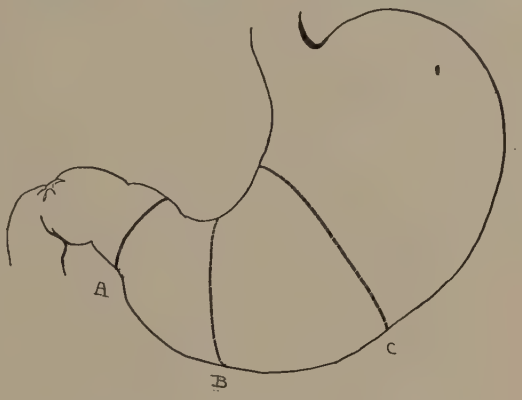


FIG. 115.—DIAGRAM SHOWING LINES OF DIVISION OF STOMACH FOR THE OPERATION OF DEVINE.

The incision to be adopted depends largely upon the location of the lesion and the facility with which the stomach divided at any one of these lines can be brought through the mesocolon.

Sherrington and Hunter have shown that when the sympathetic supply to the lower bowel is divided, the constant impulses which the sympathetic throws off and which affect the posture of the lower bowel, are abolished. The function of the parasympathetic nerves, acting intermittently, is to empty the lower bowel. The sympathetic supply acts continuously. The sympathetic system takes the strain and stresses of life and is doubtless subject to psychic influences. A spastic stomach or a spastic pyloric sphincter that does not permit normal regurgitation of the alkaline contents of the duodenum into the stomach results, according to Devine, in a condition in which the pyloric portion of the stomach is subject to high acidity, and the concentrated acid of the gastric juice is ejected into the duodenum instead of being first partly neutralized by the reflux of duodenal contents into the stomach.

A division of the sympathetic nerve supply to the large bowel in an experimental animal causes immediate contractions and defecation. The divisions of the lumbar rami of the sympathetic were severed in a paraplegic, according to Royle, and the obstinate constipation was at once cured. Devine thinks that division of the funiculus marginalis sympathetic in the stomach of a dog increases the gastric peristalsis and lessens the emptying time of the stomach. According to Devine's views, duodenal ulcer may result from the anatomic nervous influence or gastric ulcer from a sympathetic nervous derangement, and it is important to bear in mind these principles when treating ulcers. In order to overcome the influence of deranged sympathetic

nervous impulses, Devine recommends dividing the stomach in its pyloric portion, closing the distal end, bringing the proximal end through a rent in the transverse mesocolon as in gastro-enterostomy and suturing it to the jejunum (Figs. 115-117). The distal stump of the stomach atrophies from disuse and proper alkalinization of the gastric juice is usually assured.

FIG. 116.—THE OPERATION OF DEVINE FOR DUODENAL ULCER.

The pyloric end of the stomach has been separated from its omental attachments and soft-bladed clamps have been applied. Note that the clamp nearest the cardiac portion of the stomach is applied through an opening in the transverse mesocolon.

The steps of the operation are explained in the illustrations. After dividing and tying the vessels along the greater and lesser curvatures of the stomach in the region of the proposed division an opening is made in the transverse mesocolon. A long stomach clamp is introduced through this rent and is placed on the pyloric portion of the stomach. Another stomach clamp is placed anterior to the colon and near the pylorus. The stomach is divided between these two clamps. The distal stump is whipped over

with a continuous suture of catgut, which controls the bleeding and this is inverted with another row of sutures. The proximal end of the stomach is brought through the rent in the mesocolon and united to the first portion of the jejunum by the technic of gastro-enterostomy. In this way the influence of the sympathetic in producing a constriction of the pylorus and preventing regurgitation of the alkaline contents is avoided. The quick emptying of

FIG. 117.—THE PYLORIC END OF THE STOMACH HAS BEEN CLOSED.
The cardiac stump of the stomach is brought through the opening in the mesocolon and sutured to the jejunum as in posterior gastro-enterostomy.

the stomach also assures minimum acidity. In order still more to lessen the acidity the division of the stomach may be made near its center, which will thereby exclude from the body of the stomach part of the acid secreting mucosa.

This operation should not be done, of course, in the presence of stenosis of the pylorus or duodenum, because it would close off a pyloric pouch of the stomach which has some secretion.

Lewisohn finds that fully one-third of the gastro-enterostomies at Mt.

Sinai Hospital, New York, done with the usually accepted technic, are followed by jejunal ulcer. He concludes that, for duodenal or gastric ulcer, resection of a large portion of the stomach which thereby reduces the acidity of the gastric juice is essential to cure. It seems, however, that such a radical operation should not be adopted as a routine procedure in these ulcers, though doubtless it should be done in many more cases than has been the practice in the past. My own tendency is toward an increasing performance of partial gastrectomies, particularly if there are recurrent ulcers after pyloroplasty or gastro-enterostomy. While doubtless the excision of a large portion of the stomach decreases the acidity in the remaining portion, it is questionable whether such a great decrease is always desirable. If a simpler operation, such as pyloroplasty when the ulcer of the duodenum is small, or gastro-enterostomy plus ligation of the pyloric end of the stomach when it is large, does not effect a cure, then gastrectomy or the operation of Devine should be considered.

It must be recalled that when the capacity of the stomach is reduced and its exit is enlarged, the emptying is naturally facilitated provided peristalsis is not materially interfered with. One of the greatest excitants of gastric juice is the presence of food. When the pylorus is spastic and food is not readily extruded from the stomach, its presence excites the continual pouring out of gastric juice with rather high acid content. With a wide opening in the distal end of the stomach, the food may gain a ready exit and so the stimulus for gastric juice is largely lacking.

It seems, then, as has already been emphasized, there should be no one routine operation for gastric or for duodenal ulcers. If in reasonable doubt, it would be well to do a pyloroplasty; if the duodenal ulcer produces occlusion or partial occlusion, gastro-enterostomy and further occlusion of the pyloric end of the stomach with a ligature will doubtless give relief. For recurrent ulcer, however, after either of these procedures, gastrectomy or Devine's operation should be considered. In this way a large percentage of cures will be obtained and the radical operation will be done only in patients in whom it is absolutely necessary.

**Dilatation of the Duodenum.**—Not infrequently there is dilatation of the duodenum from constriction at its terminal portion. This constriction is usually considered to be caused by pressure of the transverse mesocolon and the superior mesenteric vessels. It may, however, be due to contraction of the sphincter at the terminal duodenum. Devine thinks that derangement of the sympathetic nervous impulses, which may cause continuous contraction of this sphincter, is responsible for these cases of duodenal dilatation. He recommends gastric exclusion, already described, as a proper procedure. He finds that a lateral anastomosis of a dilated duodenum to the jejunum is not a satisfactory operation.

In a group of six cases of dilatation of the duodenum in which I made a lateral anastomosis between the dilated duodenum and the jejunum, the results have been quite satisfactory in a majority of the cases, and unless the dilatation is extreme such an operation seems indicated. In extreme dilatation in

which it seemed apparent that the dilatation was not due to the mechanical pressure of the transverse mesocolon or the superior mesenteric vessels, or to adhesions or organic stricture, but resulted from sympathetic influences that produced spasm of the terminal duodenum, Devine's operation would probably be indicated. When the dilatation results from organic or mechanical causes, however, a lateral anastomosis between the duodenum and the jejunum seems to be a very satisfactory procedure.

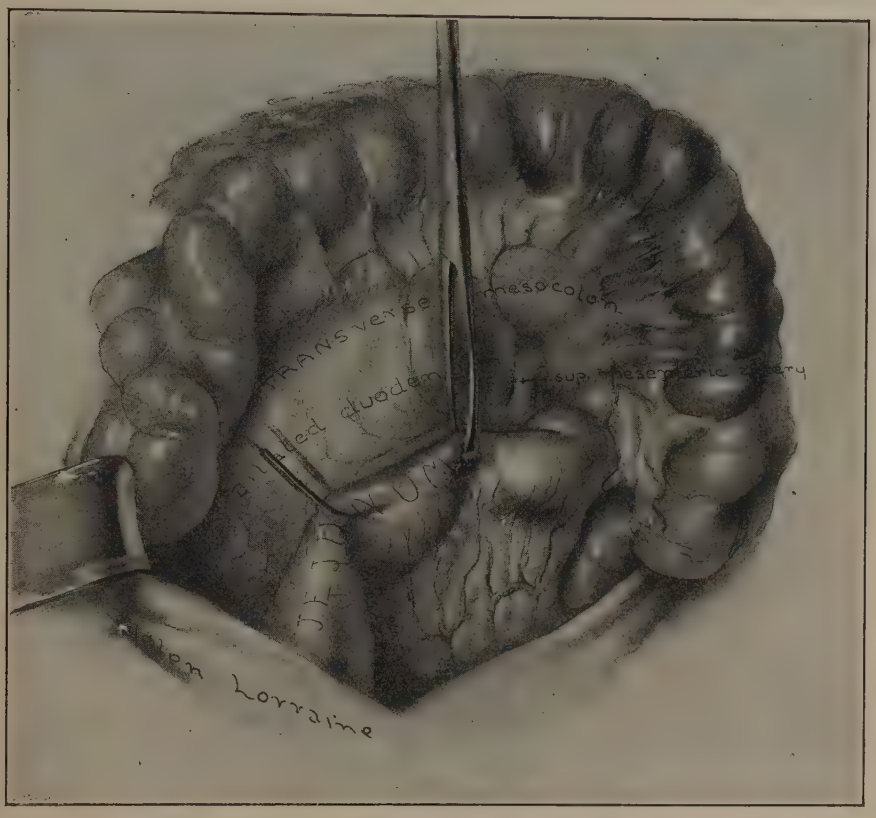


FIG. 118.—THE DILATED DUODENUM BULGES THROUGH THE TRANSPARENT MESOCOLON. A loop of jejunum is selected near the origin of the jejunum.

The operation is not difficult when the duodenum is dilated. As it is not indicated when the duodenum is normal the technical difficulties largely disappear when there is sufficient indication for the operation. The transverse colon is elevated and a loop of jejunum is selected a short distance from its origin, at such a point that there will be no tension or marked kink, and is placed beside the dilated duodenum. As the dilated duodenum bulges through the transverse mesocolon and thins it out, a point is easily selected in which there are no important vessels (Fig. 118). It is not always essential to open the transverse mesocolon. The lower portion of the loop of jejunum is fastened to the dilated duodenum with a mattress suture of 00 tanned catgut,

taking in its bite the thinned out mesocolon. If the mesocolon is thick or contains many vessels, it should be incised and the duodenum directly exposed. This suture is at the right of the proposed incision for the lateral anastomosis. At a point about 2 inches (5 cm.) to the left a similar suture is taken. The tissues are packed around with moist gauze. The loop of jejunum is united to the duodenum with a continuous right-angle suture of 00 tanned catgut. The two tractor sutures are held taut to facilitate suturing. An incision about half an inch (1.3 cm.) long is made into the duodenum about a

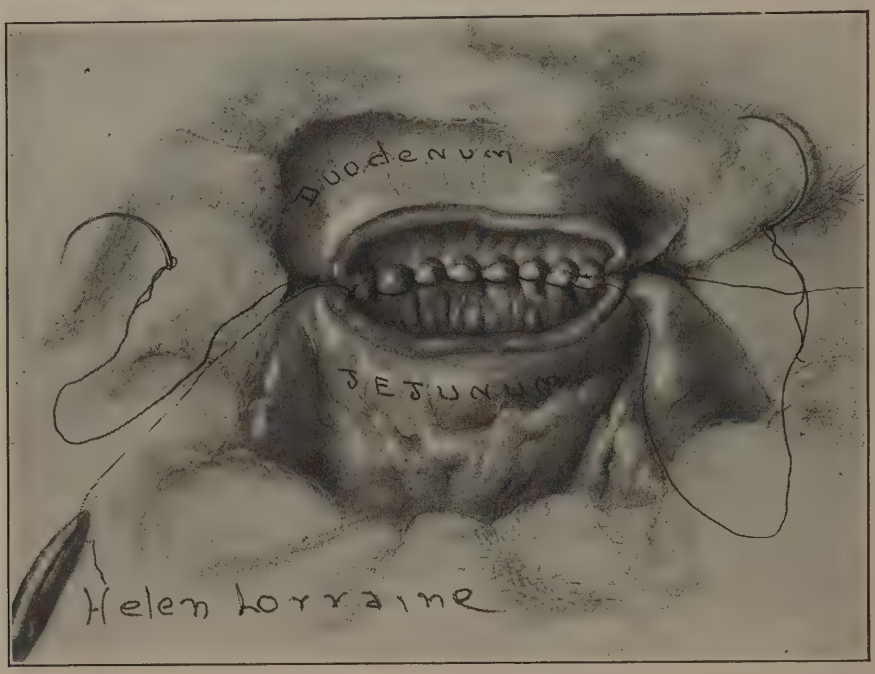


FIG. 119.—THE JEJUNUM HAS BEEN FASTENED TO THE DUODENUM WITH TWO INTERRUPTED MATTRESS SUTURES OF 00 TANNED CATGUT, AND FURTHER UNITED WITH A CONTINUOUS RIGHT-ANGLE SUTURE OF THE SAME MATERIAL.

The duodenum and jejunum are incised as in the technic for posterior gastro-enterostomy without clamps. The posterior margin of the wound in the duodenum is sutured to the posterior margin of the wound in the jejunum with a continuous lockstitch of tanned catgut.

third of an inch (0.8 cm.) from the suture line, and the contents of the duodenum are removed with a suction apparatus. The bleeding vessels are clamped with hemostats, and the incision is continued until it is 1.5 to 2 inches (3.8 to 5 cm.) in length. A similar incision is made in the jejunum. The posterior wall of the wound in the duodenum is sutured to the posterior wall of the wound in the jejunum with a continuous lockstitch of No. 1 tanned catgut (Fig. 119). This secures the bleeding points that have previously been caught with hemostats. As the end of the incision is reached the suture is continued anteriorly as a lockstitch, making no effort to bury the margins of the incision. The suture is tied to its original end (Fig. 120). The outer row of sutures is then carried anteriorly as a right-angle con-

tinuous suture, taking occasional backstitches in order to lock the sutures. When the suture is completed it is tied to the original end. As the transverse colon is replaced in position its relation to the lateral anastomosis should be noted. It is well to avoid any unusual kink or contraction that may cause undue tension upon the line of sutures at any point.

A lateral anastomosis of this kind seems much superior to operations that were formerly advocated to remove pressure from the terminal duodenum,

FIG. 120.—THIS INNER ROW OF SUTURES IS CARRIED ANTERIORLY, TAKING A SMALL BITE OF TISSUE AND MAKING NO EFFORT TO INVERT THE MARGINS.

It is tied to its original end. This row is then buried by continuing the outer row of sutures anteriorly.

such as excision of the cecum and ascending colon, which is a formidable procedure in order to secure an indirect benefit.

**Duodenal Fistula.**—A duodenal fistula may arise from trauma as a result of an operation, a stab, or a gunshot wound, or from perforation of an ulcer. A perforation into the duodenum may also be primarily from another viscus. It is not uncommon to find perforations from the gall-bladder into the duodenum when a stone ulcerates from the gall-bladder. Perforations from the stomach, colon, or small intestine may also occur. These are termed "internal fistulæ," and usually are of no serious consequence so far as the effect on nutrition is concerned, unless the perforation happens to be between the

duodenum and the lower ileum or colon so that the nutritive material is shunted to the lower bowel before there is opportunity for absorption (Fig. 121).

The external duodenal fistula, resulting from trauma or from the perforation of an ulcer which has formed an abscess and opened externally, is often very serious for it affects nutrition. The external duodenal fistula that follows

FIG. 121.—ROENTGENOGRAM TWO YEARS AND NINE MONTHS AFTER A LATERAL ANASTOMOSIS BETWEEN THE ENLARGED COMMON BILE DUCT AND THE DUODENUM.

The patient had had a previous cholecystectomy. Note the injection of even the smaller hepatic ducts by barium from the duodenum.

operation most commonly comes after operations upon the pylorus, the common bile duct, or the right kidney. The duodenum is in close proximity to the right kidney and in nephrectomy the careless grasping of vessels around the pedicle of the kidney will not infrequently involve the duodenum, and if the lumen of the duodenum is not opened at the time, the crushing may result in the sloughing of the injured tissue with a later fistulous tract. Within

the peritoneal cavity fistulæ may follow not only wounds of the duodenum that have been sutured, but wounds in the common duct or those resulting from pylorectomy.

It is important to bear in mind the prophylaxis of duodenal fistula. As has been pointed out in the section on suturing, the intestinal wound heals quickly by a deposit of lymph on the peritoneal surface. This makes a firm union within a few hours, which later becomes somewhat softer as the more permanent repair takes place. If there is any foreign body pressing upon the wall of the duodenum, the deposit of lymph is diverted in an effort to extrude the foreign body and, instead of being utilized for repair of the sutured wound, it is dissipated. In this way the suture line becomes weak and may break down. After suturing wounds of the duodenum, whether following pylorectomy or involving the duodenum primarily, no drainage should be used if it is possible to avoid it. In the presence of much sepsis the drains should be so placed as to be at some distance from the duodenum. The view seems sometimes to be held that if a tube is placed to the stump of the duodenum after a pylorectomy, for instance, and later a fistulous tract develops from the duodenum, the tube has saved the situation by draining off the contents of the duodenum which otherwise would have poured into the free peritoneal cavity. As has been already explained, this reasoning is fallacious, for the tube is usually the cause of the duodenal fistula, and if there had been nothing to divert the lymph and the healing powers of the duodenum, no fistula would have resulted.

A drainage tube in the common duct may cause an opening into the duodenum by pressure necrosis if the duodenum is in close contact with the tube. The mechanism of the disposition of a foreign body in the peritoneal cavity is interesting. Unless it is markedly septic it tends to become encapsulated by a deposit of lymph around it. The pressure on the surrounding loops of intestines seems to cause a thinning of the bowel wall. Eventually there is a tendency for the foreign body to be extruded from this surrounding capsule of lymph deposit into the lumen of the intestine. Somewhat the same process may be initiated when a large drainage tube is placed in the common duct in contact with the duodenum, and a duodenal fistula may result. When it is necessary to drain the common duct, the duodenum should be protected by bringing up a tag of gastrocolic omentum, or even of the great omentum, and suturing it over the duodenum or around the drainage tube so that the wall of the drainage tube will not come directly in contact with the duodenum. This can be readily done and may avoid a very serious complication.

A duodenal fistula that develops from a lumbar nephrectomy is always serious, because the lack of peritoneal covering of the duodenum posteriorly and the exposed tissue resulting from the nephrectomy give an ample area for the irritating effect of the duodenal contents on a raw surface, in addition to the lack of nutrition from the wasting of the partially digested food.

After a duodenal fistula has been established, its treatment depends upon the general condition of the patient as well as upon the size of the fistula.

If it develops some time after a drainage tube was applied, so that the tissue around the drainage tube is well walled off, adherent, and makes a straight canal, the tube should be withdrawn and an effort made to reduce the size of the fistulous tract by strapping the wound with adhesive or by suturing. A fistulous tract cannot be immediately closed in this way, but by diminishing its size, less of the duodenal contents will pass through the fistula and more will be carried along its normal course. When, however, the wound is large, and particularly if there is sepsis as is usual with these fistulæ, too complete a closure of the superficial part of the wound may result in the formation of pockets and the extension of the sepsis.

Cameron has employed a suction apparatus in the treatment of duodenal fistula in a patient of his. The fistula developed on the seventh day following an anterior Polya operation in which a drainage tube was carried down to the stump of the duodenum. On the eleventh day it was noted that the skin was much irritated by the discharge. The patient's general condition was good. The discharge, however, was profuse and irritating. A rubber catheter, in which several additional openings had been made, was passed into the fistulous tract as far as possible and connected with an electric suction apparatus which was kept continually in operation for eleven days. From 500 to 700 c.c. of foul colored material were removed every twenty-four hours with out any discomfort whatever to the patient. The wound cleared up quickly and the irritation of the skin disappeared. Eleven days after the suction apparatus was applied the discharge ceased and the wound healed promptly.

Such a treatment would not be applicable in patients in whom the discharge of duodenal contents through the fistula was sufficiently serious to affect nutrition. In such instances some operation must be done. The type of operation depends upon the local conditions and upon the general health of the patient. A gastro-enterostomy with occlusion of the pylorus has been advocated by Berg and in many instances is satisfactory. Naturally it would be a serious operation in a poorly nourished patient. It is usually impossible to suture the duodenum in such cases because the inflammatory products in the duodenal wall prevent the stitches from holding. If, however, the fistulous tract can be exposed without too much trauma a mass of omentum may be brought over the opening and sutured. This doubtless will not permanently close the opening unless it is done in conjunction with gastro-enterostomy and occlusion of the pylorus or with a jejunostomy which will give the duodenum rest and prevent the passage of food contents through it. Einhorn has used a jejunal tube, introducing the tube through the mouth in the usual manner of a duodenal tube and letting it pass into the jejunum. He has treated two cases of duodenal fistula satisfactorily by this method. The feeding through the tube is delivered below the site of the fistulous opening. Of course this cannot be carried out when there is pyloric obstruction or in the type of fistula that develops after resection of the stomach.

Stuart McGuire reports a case of duodenal fistula which developed following an operation for stone at the bifurcation of the hepatic ducts. The patient had been previously operated upon by another surgeon and there were many

dense adhesions. A stone had not been found at the previous operation. While separating the adhesions the duodenum was slightly injured. The gall-bladder was removed and a stone was extracted from the common duct at the junction with the hepatic ducts. The duct was drained by a tube surrounded by gauze covered with rubber tissue. On the ninth day after the operation there was a profuse discharge of gastric contents through the incision. Jejunostomy was done, inserting a rubber catheter in the jejunum by the indirect method, using the principle of Witzel. Omentum was placed about the catheter and a pint of fluid was introduced through the tube before the patient left the table. All discharge from the original drainage tube,

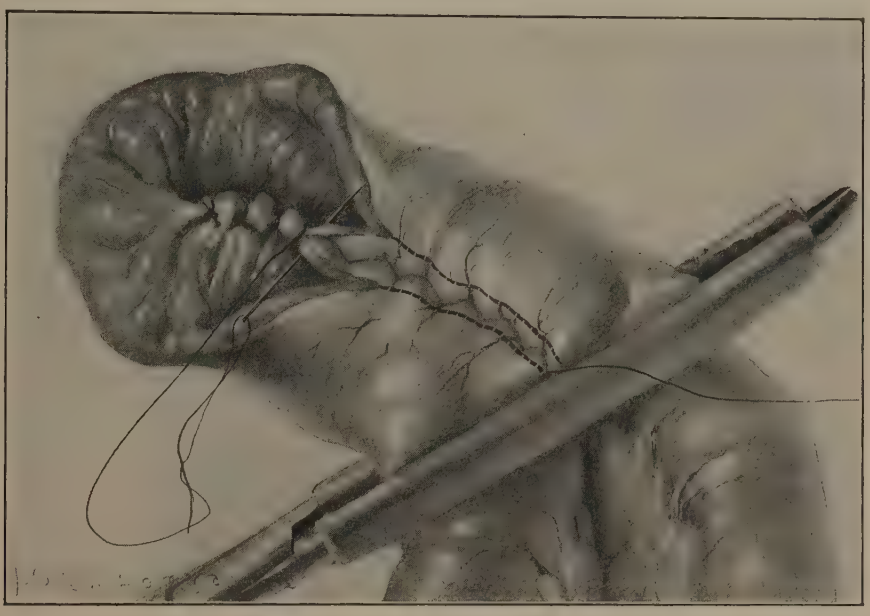

FIG. 122.—COFFEY OPERATION FOR EXCISION OF THE DUODENUM AND HEAD OF THE PANCREAS. The two limbs of a loop of jejunum have been sutured together posteriorly and are being divided anteriorly, along the dotted line, to provide a sufficiently large receptacle for the stump of the pancreas.

except bile, ceased a few days after the jejunostomy was performed. The drainage tube was removed at the end of ten days, and the patient made a satisfactory recovery. Feeding was gradually resumed by mouth.

The treatment of a duodenal fistula in mild cases, where the nutrition of the patient is not seriously affected, should consist in careful attention to the margins of the wound and protection of the skin with zinc oxid ointment and frequent dressings. If the discharge is profuse, the use of a suction apparatus would prevent damage to the surrounding tissue. When, however, the loss of fluid and food through the duodenal fistula interferes seriously with the health of the patient, and there is no obstruction at the pylorus, a jejunal tube introduced through the mouth as practiced by Einhorn may be satisfactory. When this is not possible, as in partial obstruction of the

pylorus or after excision of the pylorus, a gastro-enterostomy with complete occlusion of the pylorus (preferably with a stout kangaroo tendon) should be done. If the patient is sick and septic, and when the general condition does not permit of such a procedure, a simple jejunostomy as used in the case of McGuire should be performed.

**Operations on the Duodenum for Cancer.**—Excision of the duodenum has hardly passed the experimental stage, and yet there may be instances in which excision is justified either on account of a malignant growth originating in the duodenum, particularly in the ampulla of Vater, or because of cancer in the head of the pancreas. Incisions into the duodenum may be made and wounds closed as in any other part of the intestinal tract. Incision for extraction of stone lodged in the terminal portion of the common duct was formerly advocated by McBurney. When the duodenum is otherwise healthy such a wound should heal satisfactorily, if properly sutured, but it should not be made if there is infiltration in the wall of the duodenum, because it would doubtless break down and a duodenal fistula result.

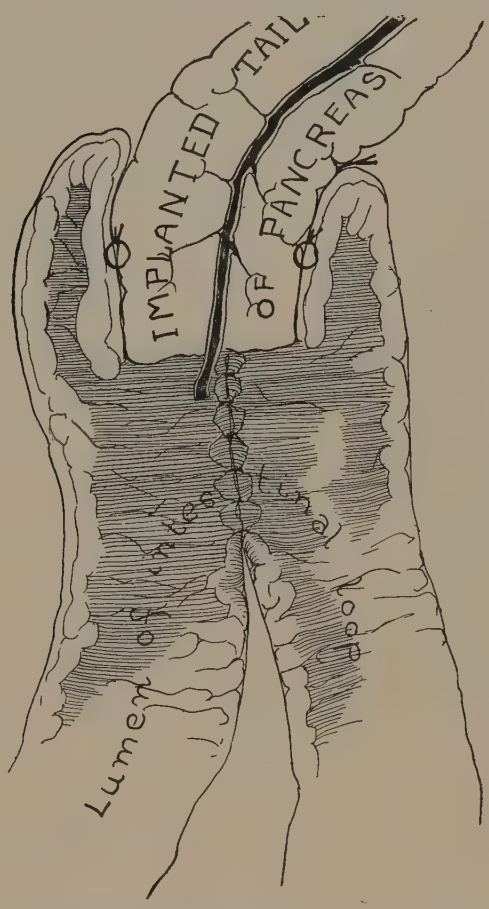


FIG. 123.—COFFEY OPERATION SHOWING THE METHOD OF IMPLANTING THE STUMP OF THE PANCREAS INTO THE JEJUNUM.

Note that the stump of the pancreas is well invaginated and securely sutured to the peritoneal coat of the jejunal receptacle.

In cancer of the ampulla of Vater, which produces biliary obstruction, a local excision may be done if the cancer is in an early stage. This, however, would be limited to a few cases in which the cancer was small and did not involve the deeper structures. When there is jaundice because of obstruction by the cancer, palliative measures are usually indicated. The jaundice may be relieved by anastomosis of the gall-bladder to the duodenum or to the jejunum.

Many surgeons advocate the anastomosis of the gall-bladder to the stomach. This is technically easier than joining it to the duodenum if the duodenum is fixed by a cancerous growth, but it is doubtful whether the eventual results are satisfactory because the gastric juice may irritate the mucosa of the gall-bladder. In some experimental work by J. S. Horsley, Jr., and his associates, in which the gall-bladder of dogs was anastomosed to the stomach

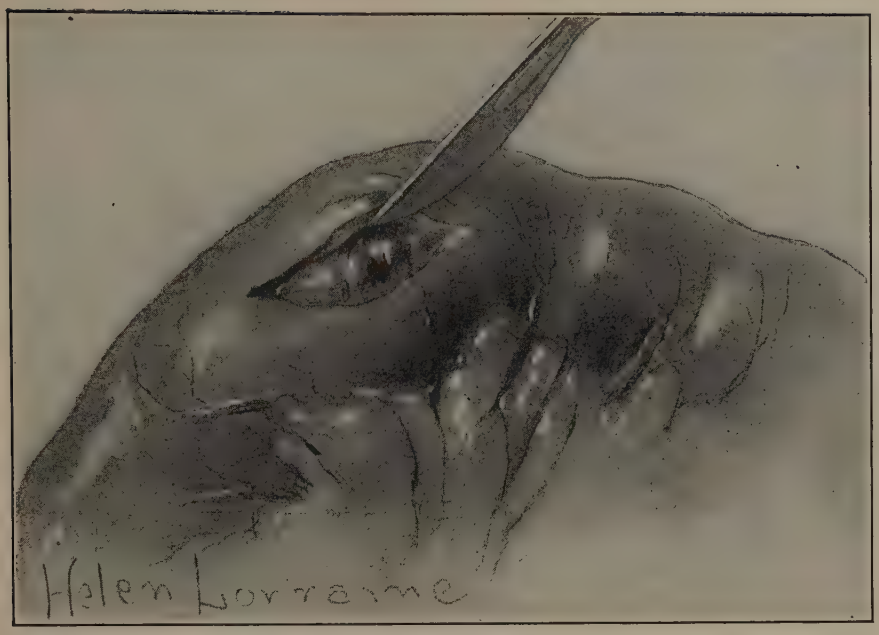

FIG. 124.—AN INCISION IS MADE INTO AN ADJOINING LOOP OF JEJUNUM FOR IMPLANTATION OF THE COMMON BILE DUCT.
The incision is carried down to the mucosa and not through it.

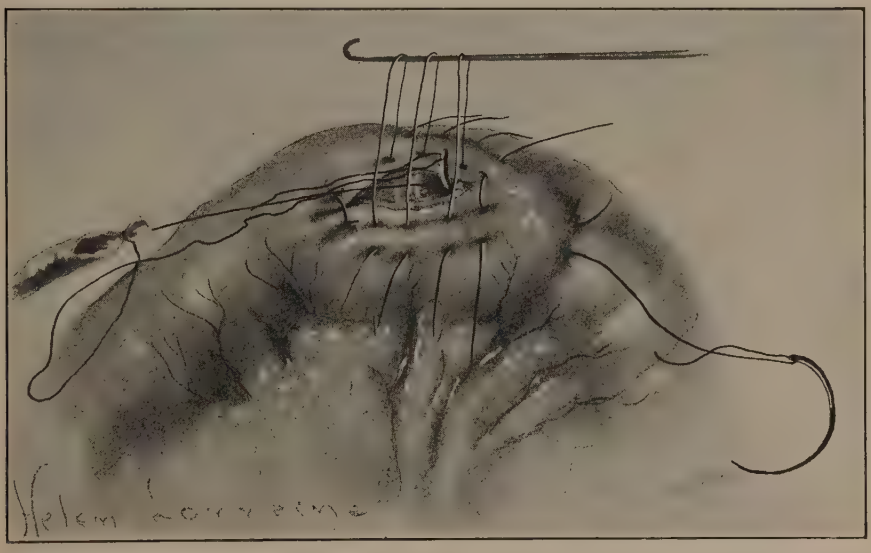

FIG. 125.—THE END OF THE COMMON DUCT HAS BEEN PREPARED AS DESCRIBED IN THE TEXT.
It is being drawn through a puncture in the mucosa at the distal end of the incision.

in a small series of experiments and to the duodenum in another series, there was apparently no marked difference; but in a clinical case in which the anastomosis was made to the stomach with relief for a few months, operation

later showed the gall-bladder greatly thickened. After cholecystectomy the mucosa was found to be much swollen. If the opening is small, it may be possible that the contractile peristaltic waves of the pyloric portion of the stomach will at least partially close the anastomotic opening during great motor activity of the stomach, but when food is accumulated under pressure at the pylorus it would seem that some of the gastric contents must necessarily be forced into the lumen of the gall-bladder.

The gall-bladder should never be anastomosed to the colon, because there is a rapidly ascending infection from the colon into the gall-bladder. Indeed some workers find that even when joined to the duodenum or the jejunum

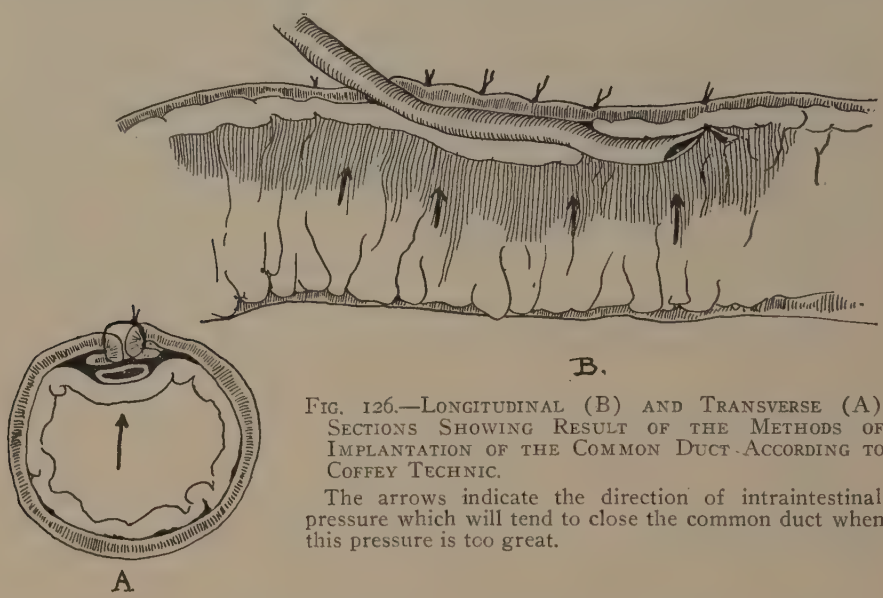


FIG. 126.—LONGITUDINAL (B) AND TRANSVERSE (A) SECTIONS SHOWING RESULT OF THE METHODS OF IMPLANTATION OF THE COMMON DUCT ACCORDING TO COFFEY TECHNIC.

The arrows indicate the direction of intraintestinal pressure which will tend to close the common duct when this pressure is too great.

where bacteria are infrequent there is eventually an infection of the gall-bladder. It would seem that the ideal place for anastomosing the gall-bladder would be to the duodenum, whose contents and whose physiologic function are already adapted to the reception of bile. If this cannot be done, the anastomosis should be made as high in the jejunum as possible. If the jejunum is unduly kinked in order to effect this an entero-anastomosis between the limbs of the jejunum will prevent an obstruction.

Irvin Abell, of Louisville, Kentucky, reported in his chairman's address before the Surgical Section of the Southern Medical Association in November, 1923, three cases of carcinoma of the ampulla of Vater upon which he had operated. He favors a conservative operation and not excision. In one case he applied radium to the ampulla of Vater, after making an incision in the duodenum. The capsule containing radium was held over the cancer of the ampulla by a suture of catgut, and a stout thread was fastened to the capsule and drawn through the stomach, esophagus, and mouth by a stomach tube which had been introduced through the mouth and passed through the pyloric

end of the stomach and to which was tied the thread from the capsule. The duodenum was then closed. An anastomosis had been previously made between the gall-bladder and the duodenum. The patient lived in considerable comfort for eighteen months.

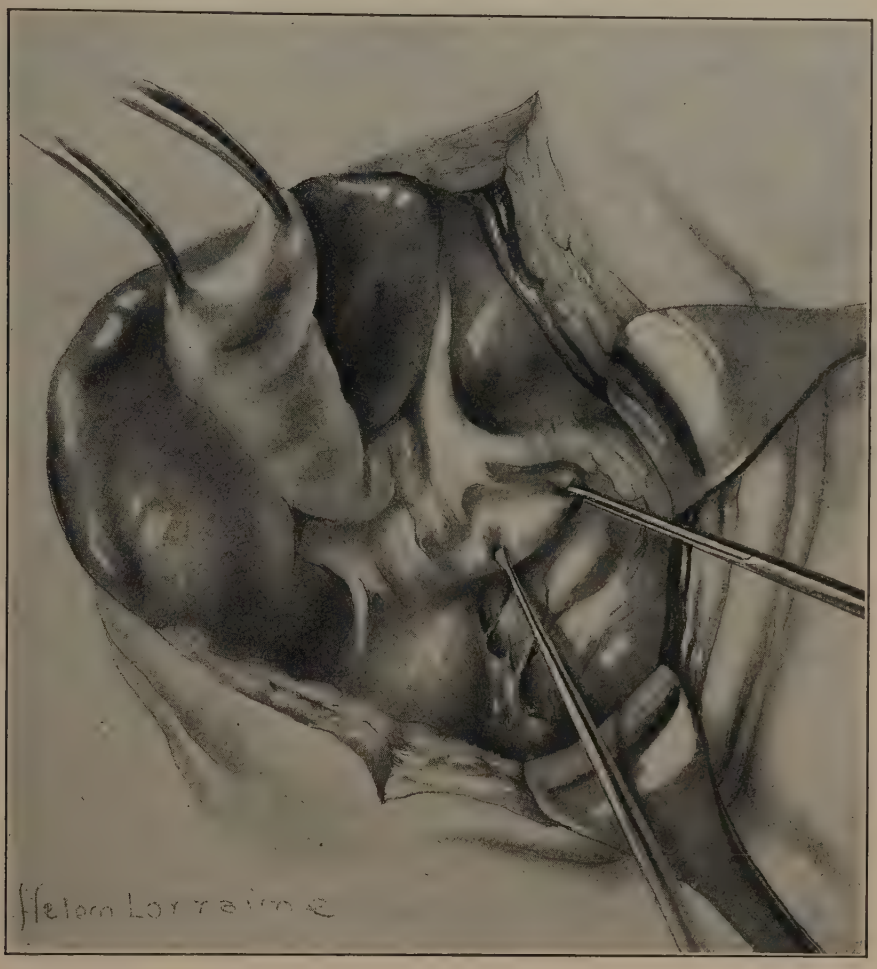

FIG. 127.—THE SITE FOR ANASTOMOSIS OF THE GALL-BLADDER TO THE DUODENUM IS MARKED BY THE APPLICATION OF FORCEPS ON THE DUODENUM.

If excision of the duodenum is indicated it will necessitate division of the common duct and usually an excision of a portion of the pancreas. This operation in the lower animals is best done in several stages, but in the human being an effort should be made to complete it as far as possible in one stage, as a two-stage operation when cancer is directly attacked is often unsatisfactory and may tend to promote a spread of the cancer. The methods of duodenectomy that have been evolved by Frank Mann, of the Mayo Clinic, of operations in several stages on animals, have shown that the duodenum can be

completely excised and the animal will remain in health. In other words, the duodenum is not essential for life, as has been supposed. The secretion from Brunner's glands seems to be of no great importance.

The technic of Coffey for excision of the head of the pancreas is also applicable to excision of the duodenum. The duodenum is exposed and mobilized as much as possible. The duodenum and the head of the pancreas are drawn forward until the portal vein and vena cava have been fully exposed. The gastroduodenal and pyloric arteries and veins are clamped, divided, and tied, and the portion of the omentum that obstructs the field is divided and tied. The common bile duct is fully exposed and severed between soft-bladed clamps. The pyloric end of the stomach is mobilized and two soft-bladed clamps are applied near this point and the duodenum is divided between them. If the pancreas is markedly affected it should be further mobilized up

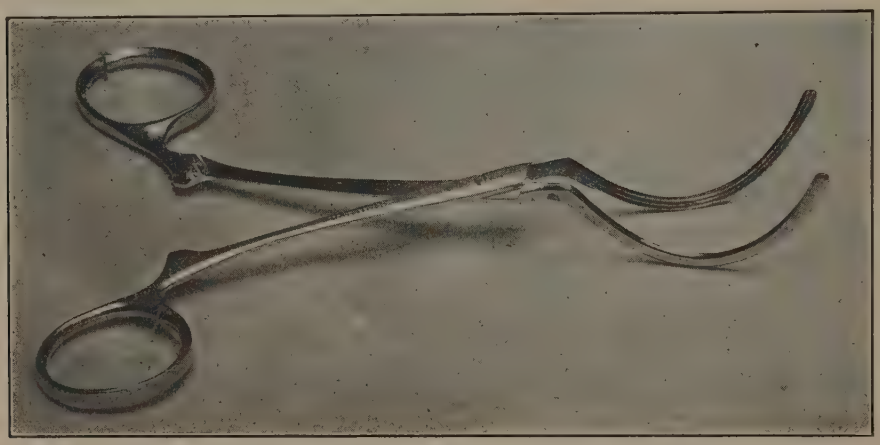

FIG. 128.—THE SOFT-BLADED FORCEPS ORIGINALLY INTENDED FOR LATERAL BLOOD-VESSEL ANASTOMOSIS.

The length of the forceps is five inches. These forceps are useful in cholecystduodenostomy. (From Horsley, J. Shelton, "A New Method of Lateral Anastomosis of Blood-Vessels," *Annals of Surgery*, May, 1915, pp. 597-603.)

to or beyond the superior mesenteric vessels, and the duodenum is freed beyond the superior mesenteric vessels until its junction with the jejunum is reached. At this point the duodenum and jejunum are doubly clamped and divided. The head of the pancreas is severed, after being clamped with a soft-bladed clamp which avoids the median colic vessels, and the duodenum with the attached head of the pancreas is removed. The two limbs of a loop of jejunum are sutured together along their convex border. The sutured jejunum is incised and then sutured in such a way as to throw the cavity of both limbs together, making the combined capacity of the limbs of this loop sufficient to receive the stump of the pancreas without too much tension (Fig. 122). At the apex of the loop the peritoneal surface is inverted by mattress sutures and the stump of the pancreas is placed within this prepared receptacle. Sutures some distance from the end of the stump of the pancreas hold the pancreas in this fixed position, and the inverted peritoneal coat is carefully stitched to

the stump of the pancreas, forming a snugly fitting collar (Fig. 123). The end of the common bile duct is obliquely implanted into the adjoining portion of the jejunum after making an incision down to the mucosa for a distance of an inch and a half (3.8 cm.) (Fig. 124). The common duct is split for a fourth of an inch (0.6 cm.) from its tip and by a suture at its tip is drawn through a punctured wound in the distal part of the exposed mucosa of the bowel (Fig. 125). This tractor suture, with a needle at each end, is passed through the punctured wound so that the needles emerge a half inch (1.3 cm.) beyond the extremity of the incision. The suture is tied, thus fixing the duct firmly in position. This suture and the exposed duct are covered by a series of interrupted sutures or by a continuous suture, which approximates the peritoneal covering. In this manner the common duct is implanted obliquely into the bowel and so prevents the reflux pressure which Coffey has demonstrated as the probable cause of dilatation and malfunction of this duct when implanted directly instead of obliquely (Fig. 126). The stump of the pyloric end of the stomach is closed and a posterior gastro-enterostomy done with a loop of jejunum as in the ordinary manner. It would probably be wise to do the gastro-enterostomy at an early stage before the anastomosis with the stump of the pancreas and the common duct, so that the duodenectomy could be postponed if the conditions did not warrant it being immediately performed. If there is much traction by the loop of jejunum when it is brought up to the pancreas, or if there seems to be a possibility of obstruction, an entero-anastomosis should be performed.

FIG. 129.—IF THE DUODENUM IS VERY MOVABLE IT IS ALSO CLAMPED WITH SOFT-BLADED CLAMPS, THOUGH CLAMPING THE DUODENUM IS NOT ESSENTIAL.

Two interrupted mattress sutures at the extremities of the proposed incision are useful in stabilizing the tissues. The gall-bladder is united to the duodenum by a continuous row of right-angle sutures applied transversely on the duodenum.

**Cholecystoduodenostomy.**—This operation is usually indicated in obstruction of the common bile duct from cancer of the pancreas, though it may, of course, be performed for other conditions, such as impermeable stricture or chronic inflammatory lesions which result in occlusion of the common duct. The site of choice for this anastomosis, as has already been discussed, is the duodenum, and usually the most available part of the duodenum is the first

portion about 1 or 2 inches (2.5 or 5 cm.) from the pylorus. The gall-bladder should be carried over to the proposed site to demonstrate whether there is tension (Fig. 127). As a rule, in such cases the gall-bladder is enlarged and distended, and the anastomosis can be easily made without tension. If for any reason there is not a sufficient amount of freedom, the gall-bladder may be partially separated from its bed at the margin of the liver. It is important to see that there is no tension whatever between the duodenum and the gall-bladder.

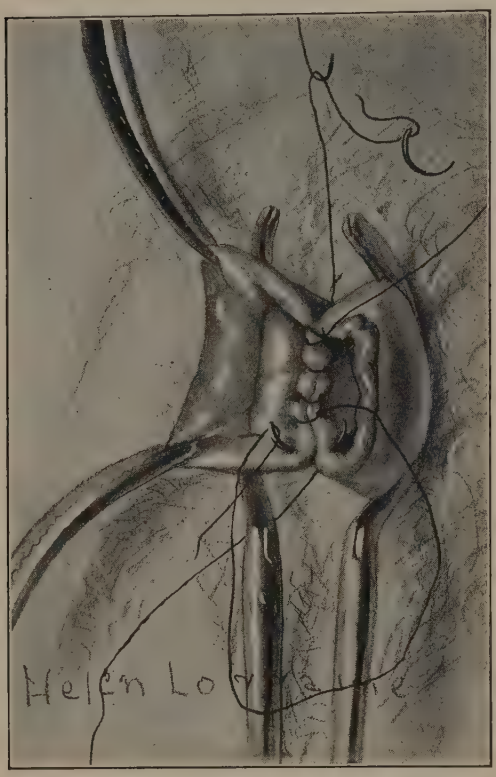

FIG. 130.—THE DUODENUM HAS BEEN INCISED TRANSVERSELY A SHORT DISTANCE FROM THE LINE OF SUTURES.

The posterior margin of the wound in the duodenum is united to the posterior margin of the opening in the gall-bladder with a continuous lockstitch, which is carried anteriorly and buried by the outer row of sutures.

If small soft-bladed clamps such as those used in lateral blood-vessel anastomosis are available (Fig. 128), this operation is rendered easier. The gall-bladder is emptied by a trocar and cannula attached to a suction apparatus, or by an aspirating needle. It is punctured at the point of proposed anastomosis. It is clamped with a soft-bladed clamp, carried over to the duodenum, and sutured with a continuous right-angle suture of 00 tanned catgut to the duodenum, preferably about an inch and a half (3.8 cm.) from the pylorus. This line of sutures is placed transversely (Fig. 129). Two tractor sutures may be inserted at the ends of the proposed incision in the duodenum, uniting the duodenum to the gall-bladder. Lifting up these sutures tends to prevent spilling the duodenal contents and makes the rest of the sewing somewhat easier. The opening in the gall-bladder is enlarged until it is about an inch (2.5 cm.) in length. A similar opening is made transversely in the duodenum. If the opening is transverse it will cut the external longitudinal muscular coat and there will be less tendency for the incision in the duodenum to be closed when the external muscular coat contracts than if the incision were made parallel with the axis of the bowel. The bleeding vessels are clamped. The contents of the duodenum are removed with a suction apparatus. When the duodenum is very mobile a soft-bladed clamp may be applied to it transversely, thus facilitating the operation. The posterior margin of the wound in the duodenum is united to the posterior margin of the wound in the gall-bladder with a continuous lockstitch of silk or linen (Fig. 130). This is carried

around anteriorly, taking a small bite of the duodenum and of the gall-bladder in each suture and making no effort to invert the anterior margin of the wound. The suture is tied to its original end. The external row of sutures is carried anteriorly as a right-angle continuous suture with an occasional backstitch. It is best applied with a small round curved needle without a cutting point. At tag of gastrocolic omentum or some peritoneal covered fat is fastened with a few interrupted stitches over the line of sutures. Care should be taken to apply the internal row snugly, as this controls the bleeding, and as it is impracticable to remove the clamp from the gall-bladder until after the operation has been completed, because the wound might be flooded with bile. The vessels in the gall-bladder at this point are small. The duodenum is usually anastomosed without clamps and the bleeding vessels from this source, which are more important, are obvious because they have not been occluded by a clamp.

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## CHAPTER XV

## THE JEJUNUM AND ILEUM

**Wounds in the Small Intestine.**—Wounds in the small intestine may be of any shape, size or condition, and should be repaired upon the general principles of intestinal suturing which have already been discussed. When there is much contusion it is best to trim away the contused tissue and suture the freshly cut intestinal margin. In the presence of chronic infection or inflammation, when the walls of the intestine are thickened, sutures will not usually hold even if carefully applied, and it is best either to resect a larger portion of the bowel until normal healthy intestine is found, or else to bring the loop of bowel to the abdominal wound and establish a fecal fistula. If this latter procedure cannot be done the wounded intestine should be covered with omentum loosely packed around it, and a soft rubber tube placed nearby to drain off fecal contents which will be likely to follow.

Wounds in the upper small intestine are treated differently from wounds in the lower small intestine, partly on account of anatomical and physiologic conditions of the tissue itself, and partly because a large fistulous tract in the upper part of the small intestine seriously impairs nutrition, which is not materially affected by a fistulous opening in the terminal portion. The type of suture should depend upon the character of the wound. If there is marked bleeding from the margins, it is best to approximate them with a continuous suture of 00 tanned catgut, catching a very small bite of tissue, which is buried with a continuous right-angle stitch of silk or linen. As little tissue as possible should be inverted, because the lumen of the small bowel is easily encroached upon. If there are only one or two spots of bleeding, they may be caught and tied in the usual manner and a single row of right-angle continuous sutures applied (page 129).

**Diverticula.**—Diverticula of the jejunum and of the duodenum occasionally occur. They are sometimes found incidentally in abdominal operations for other conditions. They do not always cause symptoms. They are often multiple. In the jejunum they usually appear along the mesenteric border. They are not infrequently found by roentgenologic examination conducted for symptoms of gastric disorder (Fig. 131).

Frank Helvestine, Jr., of the University of Virginia, after reporting two cases of diverticula of the jejunum, reviews the literature on this subject. He concludes that the acquired diverticula of the jejunum are probably true diverticula in the early stages, the sac containing a continuation of the muscular coat of the bowel. As they enlarge, however, they tend to become false diverticula by the disappearance or degeneration of the muscular coat.

The treatment depends upon the present or the potential danger of the

diverticula. If they are not inflamed and are in the jejunum, they can frequently be readily removed by careful dissection around the neck of the diverticulum, pulling it up, and tying the neck as in ligation of the stump of the appendix. The ligature is linen or silk. The diverticulum is clamped and cut away, and the stump is cauterized with pure carbolic, and covered with neighboring peritoneum. If the base is broad a more extensive operation is necessitated. Care should be taken to leave an ample intestinal lumen at the base of the diverticulum.

N. J. MacLean reports a case of excision of diverticulum of the duodenum in which the diverticulum pointed toward the pancreas. The duodenum was

FIG. 131.—MULTIPLE DIVERTICULA IN THE UPPER JEJUNUM DISCOVERED DURING OPERATION FOR OTHER ABDOMINAL LESIONS.

Most of them were removed by exposing and tying the neck of the sac close to the bowel and excising the diverticulum.

incised about opposite the diverticulum, the finger was inserted through the duodenum into the sac, an incision was made over it and the sac was freed while retaining the finger in it. It was then invaginated into the lumen of the duodenum, the pedicle was tied, and the diverticulum was cut away.

Resection of a jejunal segment containing a diverticulum and end-to-end union may be indicated. Such treatment, however, depends upon the diverticulum. If it is markedly inflamed its removal should be by resection of the bowel.

Meckel's diverticulum is an embryologic remnant sometimes found in the ileum, 1 to 2 feet (30 to 60 cm.) from the ileocecal valve. It results from the persistence of the vitelline duct, which has been described in the chapter on embryology, and is sometimes a source of inflammation or of

obstruction. If the tip of the diverticulum is attached to the neighboring tissue it may act as an axis around which loops of bowel gather, producing a volvulus.

It is impossible to make a diagnosis of the cause of obstruction in such cases, except as a general surmise. It is questionable whether Meckel's diverticulum should be removed if it is giving no symptoms. It is undoubtedly a source of potential danger, and if it is discovered incidentally in doing other abdominal operations its resection would depend largely upon the general condition of the patient and upon the character of the diverticulum. If the tip is attached or inflamed, the diverticulum should be removed. If the patient is in good condition and the diverticulum is easy of access, it might be wise to remove it even without the indications mentioned.

The bowel at the base of the diverticulum is clamped with soft-bladed intestinal forceps. Another clamp is placed on the diverticulum and, after this loop of ileum is thoroughly surrounded with moist gauze, the diverticulum is cut away. This may be done with an electric cautery, leaving a margin of the ileum exposed in the clamp. The margins of the wound are whipped over with a continuous suture of fine tanned catgut. The clamp is removed and the row of sutures is buried with a continuous right-angle suture of fine linen or silk. It would be possible to utilize the technic of Kerr in applying crushing forceps and burying the stump with a basting stitch (page 279), but this might involve the inversion of too much tissue and produce an obstruction. If a light clamp is used and the cautery employed for severing the base of the diverticulum, and the portion of bowel wall caught in a soft-bladed clamp is cleaned with antiseptic sponges, the danger of infection should be very small. It must be remembered, too, that there is at this point no loose areolar tissue as along the mesenteric border, in which infection so readily begins.

## INTESTINAL RESECTION

In resection of the small bowel it is essential to bear in mind the anatomic and the physiologic conditions. The intestine can be identified not only by its general position in the abdomen, the jejunum occupying the upper left portion and the terminal ileum the lower right iliac fossa and the pelvis, but by the appearance of the intestine itself, which Monks has clearly pointed out (page 20). The upper small intestine or jejunum has rapid and active peristalsis. Alvarez has laid great stress upon this, and has shown that the normal rhythmical contraction in the upper jejunum is about 20 per minute, whereas in the lower ileum it is 12 per minute. Most of the digestion and absorption in the gastro-intestinal tract takes place in the small intestine. There are large valves of mucous membrane which increase the area of the internal surface of the bowel and afford greater capacity for absorption. Naturally, with greater activity and absorption there is a greater supply of blood and lymph. There are few bacteria in the upper small bowel, so that spilling the intestinal contents in this region is not such a serious matter as

would be in the lower ileum, though of course it should be avoided. In the lower ileum the function is quite different. The fecal contents teem with bacteria. Spilling the smallest portion is likely to be followed by serious infection. The mesentery of the ileum is more infiltrated with fat than the mesentery of the upper jejunum, and consequently the triangular space, on the border of the intestine, where the two layers of the mesentery separate to surround the intestine, is greater. The peristalsis being slower, there is not the same active response to stimulation and infringement upon the lumen of the bowel as would occur in the jejunum. It is evident, then, that for these reasons as well as for others described in the chapter on physiology, the difference is so great that the same technic cannot be successfully applied both to the upper jejunum and to the lower ileum.

The triangular mesenteric space that has been referred to is of vital importance in resection of the bowel, particularly in end-to-end resection. It was formerly the practice of many surgeons to divide the bowel from the convex to the mesenteric border. In this way the blades of the scissors that sever the mucosa of the intestine also cut into this triangular space, and of necessity carry the infection from the bowel contents and from the mucosa into this space filled with loose areolar tissue and lymphatics. The absorptive power here is rapid and after once becoming infected such tissue is difficult to clean. In any technic involving the division of the bowel the lumen of the bowel should never be opened until after the mesenteric attachments have been clamped, divided and tied. After the triangular space at the mesenteric border has been clamped and occluded by a secure ligature, then the bowel is divided from the mesenteric border outward, so that the tips of the scissors point away from the mesenteric border and cannot infect this triangular space. It has been objected that end-to-end union of the intestine was not satisfactory because it broke down at the mesenteric border, and the reason given for this breaking down was that this border was not covered with peritoneum and consequently did not heal readily. The real cause for leakage, in many instances at least, was infection carried by the blade of the scissors, and though the triangular mesenteric space was sealed after it was infected, naturally the infection would arise later at this point and cause the sutures to give way.

It is never necessary to have a peritoneal covering on more than one side in suturing intestine, but it is essential to have it on one side. In making the union one end of the bowel should be slightly rotated so that the triangular mesenteric spaces, instead of lying opposite each other, are side to side. In this way a layer of smooth peritoneum, at least on one side, is always secured.

The advantages of end-to-end and of lateral anastomosis have been much discussed. Many years ago I attempted to call attention to the advantages of the end-to-end method of union of the bowel as opposed to the lateral method and emphasized the fact that the objection of leakage could be overcome in most cases by methods such as have been above described. Undoubtedly there are instances, however, in which lateral anastomosis is indicated. When the mesentery is exceedingly fat and the infolding of the bowel at the mesenteric border would too greatly reduce the caliber of the intestine,

an end-to-end union may be followed by obstruction. Then, too, where there are sharp kinks or where a loop of intestine is involved in extensive inflammation which threatens to become a strangulation, a lateral anastomosis without resection is indicated.

No surgical technic is satisfactory if it is not founded upon the essential anatomic structure and physiologic function of the involved tissue. It is obvious, then, that a resection in the upper jejunum with its rapid active peristalsis and its low bacterial content must be made in such a manner as not to interfere too greatly with its motility. A slight obstruction of the lumen is keenly felt by a hyperactive bowel, and in this region an obstruction is more rapidly fatal than lower down. In the lower ileum with high bacterial contents and slower peristalsis, it is not so essential to secure a large lumen after the suturing as it is to prevent soiling of the tissues by the escape of any fecal matter.

An end-to-end union after intestinal resection is the usual method of preference at any point throughout the intestine, while lateral anastomosis as a routine measure has many disadvantages. Cannon and Murphy many years ago pointed out the disadvantages of lateral intestinal anastomosis. The action of the inner layer of circular muscle of the intestine is destroyed by the incision in lateral anastomosis, so a column of food within the lateral anastomosis must be shoved through the site of the anastomosis by the peristalsis of the circular muscular fibers on the oral side of this incision. This was shown experimentally by always finding some intestinal contents in or near the lumen of the lateral anastomosis, and it can be also demonstrated by roentgenograms. With a blind pocket at each end, the action of peristalsis, particularly on the oral side, forces the fecal matter into these pockets and accumulation occurs which may end disastrously. If a lateral anastomosis must be made, it is essential to place the incision close to the blind ends, so as to avoid pocketing. In time a lateral anastomosis tends to straighten itself by twisting the bowel in such a manner that the current of fecal matter is not too greatly deflected as it passes through. In end-to-end union, however, there is no stasis at the point of resection. The function of neither the longitudinal nor the muscular fibers is impaired. Alvarez has shown that the rhythm and motion of the intestine are to a large extent myogenic in origin. As the nervous conduction of peristalsis is not important, there is often but little interference with function even a few days after an end-to-end union has been completed. The eventual result is often so perfect as to make it difficult to detect the site of the union after a few months.

In the jejunum, then, and particularly in the upper jejunum, a technic should be adopted whose prime object is to secure a satisfactory union of the two bowel ends in such a manner that the lumen is not obstructed and that the function of the intestinal muscle is not impaired. The loop of bowel to be resected is delivered into the wound as far as possible and the surrounding bowel and tissues are packed off with pads or sheets of gauze wrung out of warm salt solution. If the exposure of the bowel is extensive, it may be best to use dry gauze which does not cause such rapid chilling of the bowel

and is more likely to preserve the heat. Loss of heat and trauma during any abdominal operation tend to promote shock, and should be avoided as much as possible. In some instances it may be impossible to isolate the affected loop without at the same time delivering a considerable adjoining portion of the bowel; and here the loss of heat should be prevented by covering the bowel with many layers of dry gauze and by placing next to the affected loop moist gauze which does not have the same capacity as dry gauze for spreading any bowel contents that might accidentally spill.

Not only should the loop of affected bowel be inspected, but the adjacent healthy portion should be examined. If the operation is to be done for such affections as mesenteric thrombosis, the vitality of the intestine adjoining the obviously diseased segment is often affected, and it is much better in such instances to take out the suspicious bowel than to leave it. If the intestine is united where its nutrition is not satisfactory, and if the thrombus later spreads so as to cut off its nutrition still more, healing at the suture line will be impaired and leakage will probably occur.

Before any steps are taken in the resection the bowel should be thoroughly surveyed and it should be determined definitely that the proposed site of the resection goes through healthy tissues that are well nourished. Sometimes when there is much fat it is impossible to tell this definitely until the mesentery has been incised. When the mesentery is cut close to the lumen of the bowel and does not bleed freely, with spurting vessels, it is significant and should be considered an indication for exploration of the bowel farther away from the lesion.

The mesentery is clamped in sections and divided, preferably close to the bowel, unless the mesentery is markedly involved. A thrombus from a ligated vessel may extend in a cardiac direction in the artery, and it is well to give space for this accident. Clamping the mesentery close to the bowel at the ends of the proposed resection avoids the possible injury of an important mesenteric branch that may supply the ends. Such a misfortune might impair nutrition seriously and result in leakage. Consequently, it is a good rule, to which there are a few obvious exceptions, to sever and clamp the mesentery close to the bowel. After this has been done, the mesentery is tied in sections with plain catgut. Care must be taken to run the knot down smoothly and to use only one twist, because in a fatty mesentery the fat may later soften and so loosen the knot as to permit bleeding. It is best to tie the knot in the groove made by the clamp. The first loop in the knot may be held with mosquito forceps, which do not injure the suture and will prevent loosening of the first loop of the knot while the second one is being made. The knot should be tied at least three times.

When the triangular mesenteric space has been incised it is clamped with forceps, and the tissue within the grasp of the forceps is tied, preferably with linen or silk. In the subsequent suturing there is much manipulation around this region and it is somewhat safer to use linen or silk than catgut. A ligature makes a better closure without the possibility of opening into this space than a suture would.

After the loop which is to be resected has been completely severed from its mesentery and the triangular space has been clamped and tied, moist gauze is placed under the loop to protect the stumps of the mesentery that have been tied. The bowel is clamped with a soft-bladed intestinal clamp about three or four inches (7.7 or 10.2 cm.) from the point of proposed resection. The intestinal contents are stripped up with two fingers into the segment that is to be resected and a stout straight pedicle forceps is applied along the proposed line of division, not at a right angle to the bowel, but slightly obliquely so that when the bowel is severed parallel to the clamp the line of incision will go from the mesenteric border outward toward the healthy portion of the intestine (Fig. 132). This not only insures a larger lumen than would be obtained by an incision at right angles to the axis of the bowel,

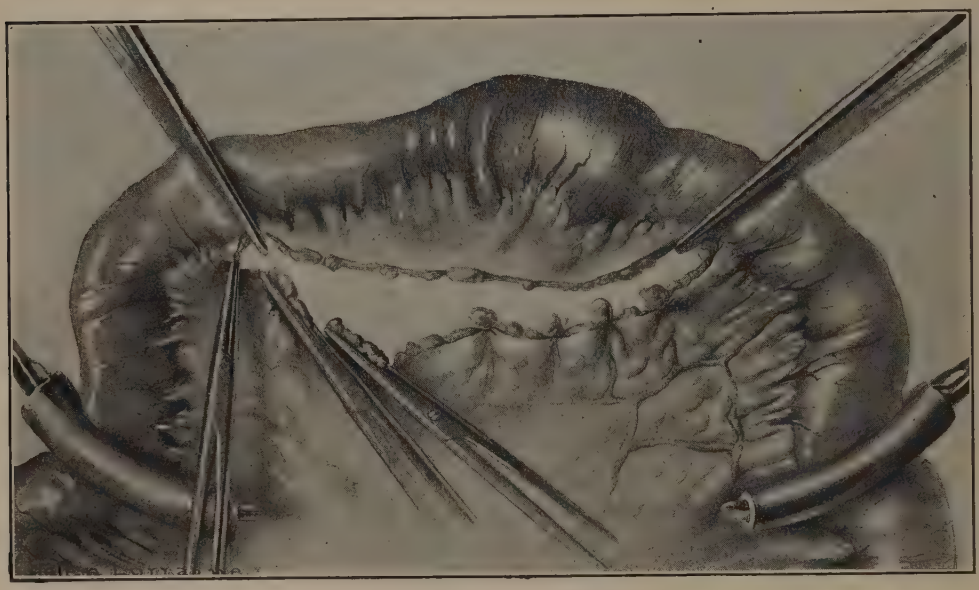

FIG. 132.—RESECTION OF THE JEJUNUM.

The loop of bowel has been severed from its mesentery. The triangular space has been clamped and tied on one side and is clamped on the other. Note that the clamps on the ends of the affected loop are placed obliquely and not at right angles to the bowel.

but also provides for a better blood supply. It is unnecessary to make the incision with the cautery, for the lumen of the bowel must be opened later so no advantage would be obtained by using the cautery. The incision is made with scissors close to the pedicle forceps from the mesenteric border outward. As the bowel is opened its margin is caught with mosquito forceps and held so as to prevent spilling the contents. If the contents have been properly milked out with two fingers, as has been described, before applying the clamp on the end of the affected loop, there should be but little to be spilled. It is important to watch this end of the bowel carefully, and, as the intestine is being severed, to grasp different points along its margin with mosquito forceps until the bowel has been completely divided.

The end of the diseased loop is covered with several layers of moist gauze

and placed so that it cannot contaminate the surrounding tissue. The stump of the bowel, which consists of that portion from the incision to the intestinal clamp, is gently cleaned with moist strips of gauze dipped in some antiseptic solution. After this has been done a moist strip is lightly packed into the stump which is covered with a gauze sheet. It is necessary to use great gentleness in manipulating the mucosa, because rough handling with dry gauze would injure the mucosa, cause bleeding, retard healing, and may be productive of many unfortunate complications. The stump at the

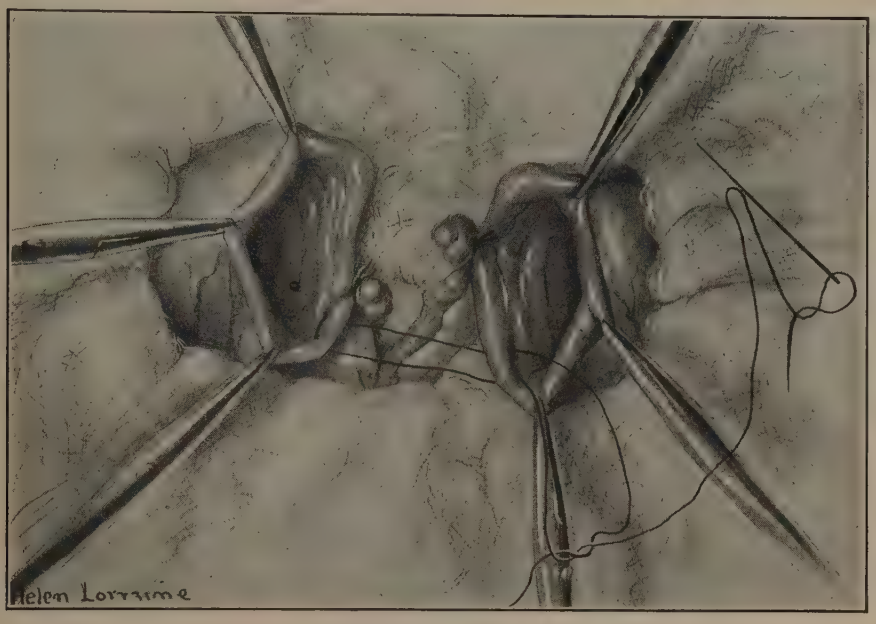


FIG. 133.—RESECTION OF THE JEJUNUM.

The ends of the bowel are so placed that the ligated triangular spaces will be side-by-side when the intestine is sutured. The first stitch begins on the right end of the bowel. The needle penetrates from the mucosa to the peritoneum about one half of an inch from the mesenteric border. It is carried to the left end of the bowel which is entered from the peritoneal surface and it returns in a reverse direction. It is tied snugly and the short end is clamped.

other end of the resected segment is similarly treated. The bowel is then ready to be united.

The intestinal clamps should be handled as little as possible, for the manipulation may displace them and permit the two stumps of the bowel to be flooded with fecal contents, which would be exceedingly unfortunate. The two bowel ends are brought together in such a manner that there is no tension upon them and so placed that the ligated triangular spaces on the mesenteric border are side by side and not opposite each other. A continuous mattress stitch of linen or silk is begun on the mucosa of the end of the bowel at the operator's right. This penetrates the whole bowel wall from the mucosa outward, about one-fourth inch to a half inch (0.6 to 1.3 cm.) from the mesenteric border. The needle is carried across from the right to the left

end of the intestine and penetrates the left end from the peritoneal surface about one half to three-fourths inch (1.3 to 1.9 cm.) from its mesentery. In other words, the suture is so placed as to insure that the two ligated triangular mesenteric spaces are side by side, not opposite. The suture returns in a reverse direction, passing from the mucosa to the peritoneal surface in the left end of the bowel, and from the peritoneal surface to the mucosa in the right end (Fig. 133). It is then tied snugly and the short end is

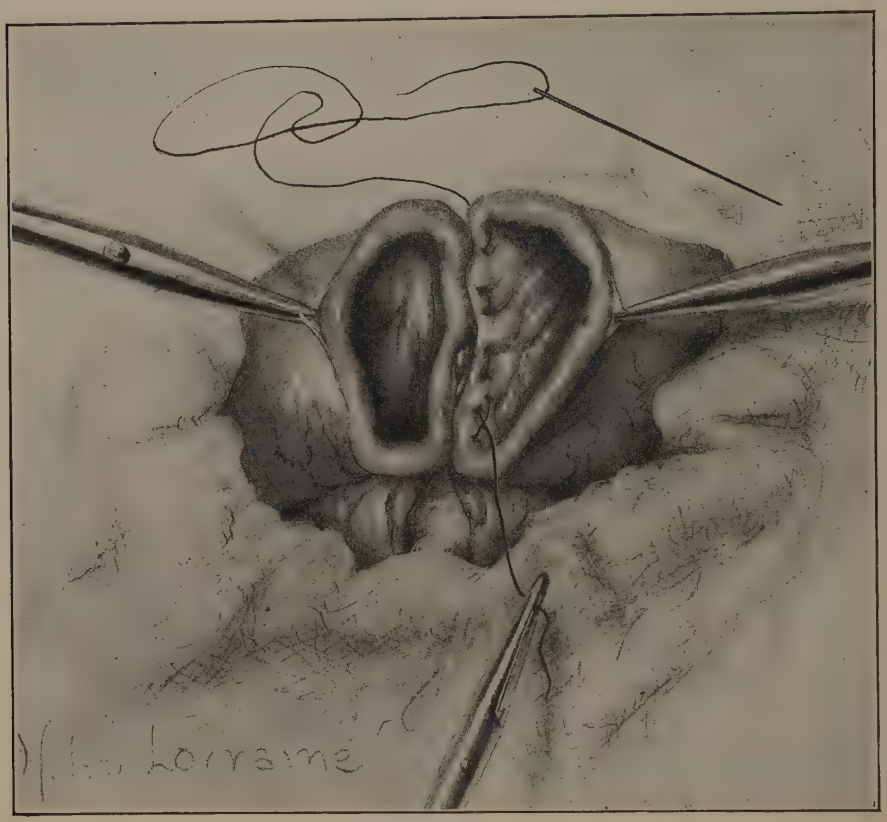

FIG. 134.—RESECTION OF THE JEJUNUM.

The needle is passed back and forth after the manner of a continuous mattress suture, catching all coats of the bowel until about one-third of the circumference has been sutured. The needle is then thrust through the bowel wall from the mucosa to the peritoneum, and a backstitch is taken to lock the sutures at this point.

clamped with forceps. It is passed back and forth as a continuous mattress suture, drawn snugly, and a portion of the stumps of the ligated triangular mesenteric spaces is caught in the suture. In the first third of the circumference of the bowel the sutures are drawn more snugly than in the other two-thirds, because the mesenteric border requires more tension for accurate approximation.

After about a third of the circumference of the bowel has been thus sutured, the needle is thrust through from the mucous surface to the peritoneum

(Fig. 134). A backstitch is taken at this point to lock the suture. If the mucosa has not fallen into fairly accurate line, a continuous suture of fine tanned catgut may be applied lightly, uniting the mucous membranes of this third of the bowel. The suture, however, should not be made tight, but should barely approximate the mucosa (Fig. 135). In this way an additional protection is given to the mesenteric border of the bowel and at the same time there is no additional obstruction to the lumen, which would occur if a second row of sutures were applied externally. When the mucosa is redundant and

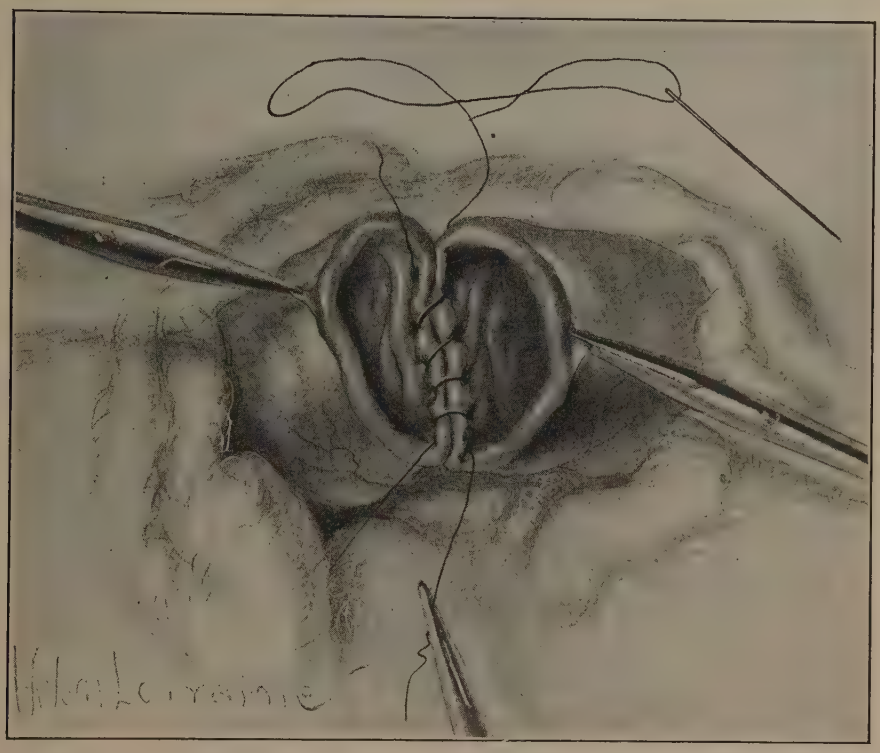

FIG. 135.—RESECTION OF THE JEJUNUM.

If the mucosa does not satisfactorily cover the ligated stumps of the triangular space and adjacent tissue, a continuous suture of fine tanned catgut lightly unites the mucous membrane of this third of the bowel that has been sutured. No knots are made in this suture.

readily falls together as a flap or valve, and there is not much fat, this suture in the mucosa may not be necessary, but it is easily applied and probably adds to the protection of this portion of the bowel if it is not made tight. It is somewhat safer to use it. The original suture is then taken up and continued as a right-angle continuous suture, penetrating all coats and turning in only enough of the margins to secure accurate approximation of the peritoneal surface (Fig. 136). About every third or fourth stitch should be a backstitch. During the suturing there is a tendency for the contraction of the external longitudinal muscular coat to evert the mucosa and produce a cuff. This can be turned in by the stitches as they are taken,

but the inversion is facilitated by gently pressing down the margins of the bowel with thumb forceps while the stitch is tightened. The suture is drawn snug, but it should not be too tight. If drawn too tight, necrosis may

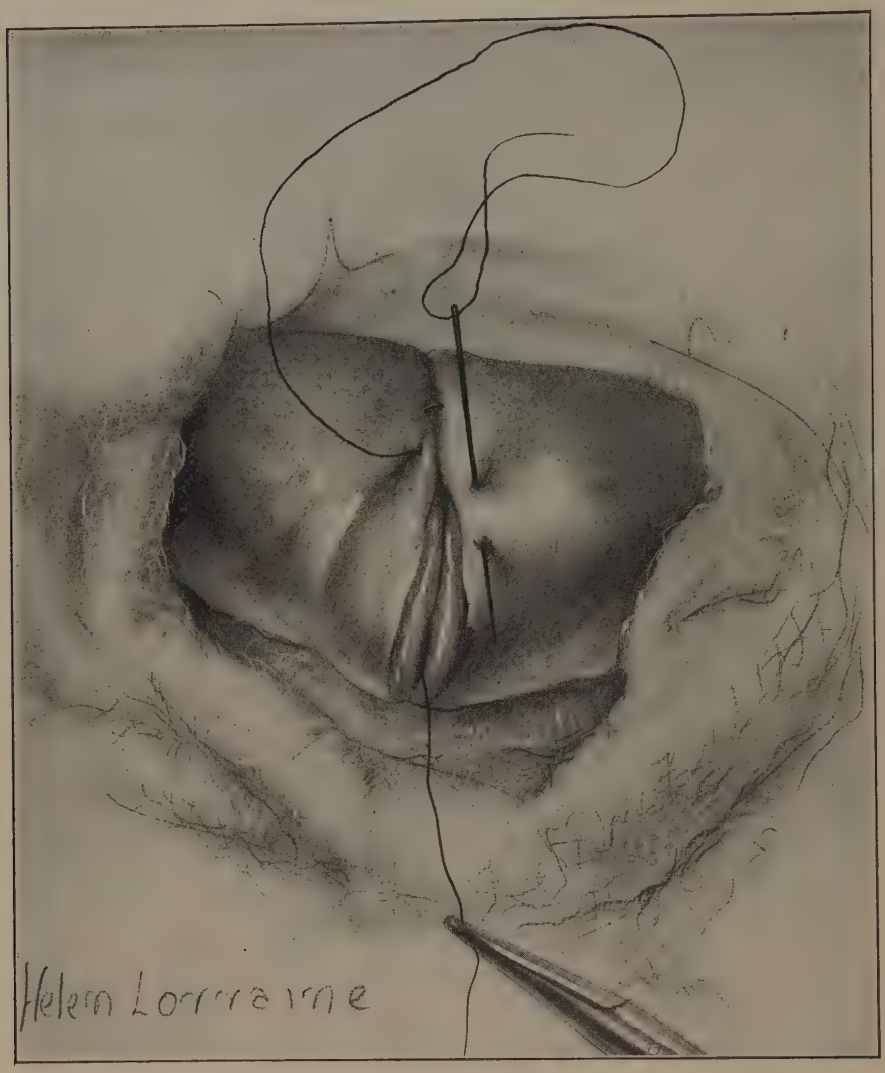


FIG. 136.—RESECTION OF THE JEJUNUM.

The original suture is taken up and continued as a right-angle continuous suture, penetrating all coats of the bowel, and approximating the peritoneum along the intestinal margin. It is drawn snug, but not too tight. A backstitch is taken at every third stitch.

occur, a danger which has already been referred to; and, in addition, the bowel may be gathered up as on a basting stitch and the lumen be occluded as in the application of a purse-string suture.

When the suture has reached the point of beginning, a backstitch is taken to lock it and the suture is carried about one stitch beyond the short clamped

end of the original knot of the suture. This should be so arranged that the last stitch is on the left end of the bowel. It is then tied three or four times snugly, but not too tight, to the original end (Fig. 137). This infolds the last margin of the intestine and secures accurate peritoneal approximation by pulling up the mobile peritoneal surface on the left end of the bowel toward the knot which is fixed within the intestinal lumen on the right end. After

FIG. 137.—RESECTION OF THE JEJUNUM.

When the suture has reached the point of beginning, a backstitch is taken and an additional stitch is made beyond the clamped short end of the original knot. The suture is tied snugly three or four times to the original end.

the end has been tied the knot is cut short and is drawn into the intestine. If any portion of it is exposed or if there is any reasonable doubt about the safety here an interrupted mattress suture of silk or linen is placed over the knot.

It must be recalled that one of the main objects of this technic is to leave a patent lumen in which there will be a minimal amount of diaphragm compatible with a satisfactory union of the apposed peritoneal surfaces. When the union has been completed the finger and thumb should gently

invert the bowel on each side of the union to demonstrate that the lumen is ample. If the lumen appears materially smaller than the normal, or if there is a suggestion that it is tight enough to cause obstruction when swelling supervenes, it is safer to undo the anastomosis and begin over again, or at least to do the last two-thirds over again. The thread for the first two-thirds can be anchored by tying it by the forceps methods to the end of the

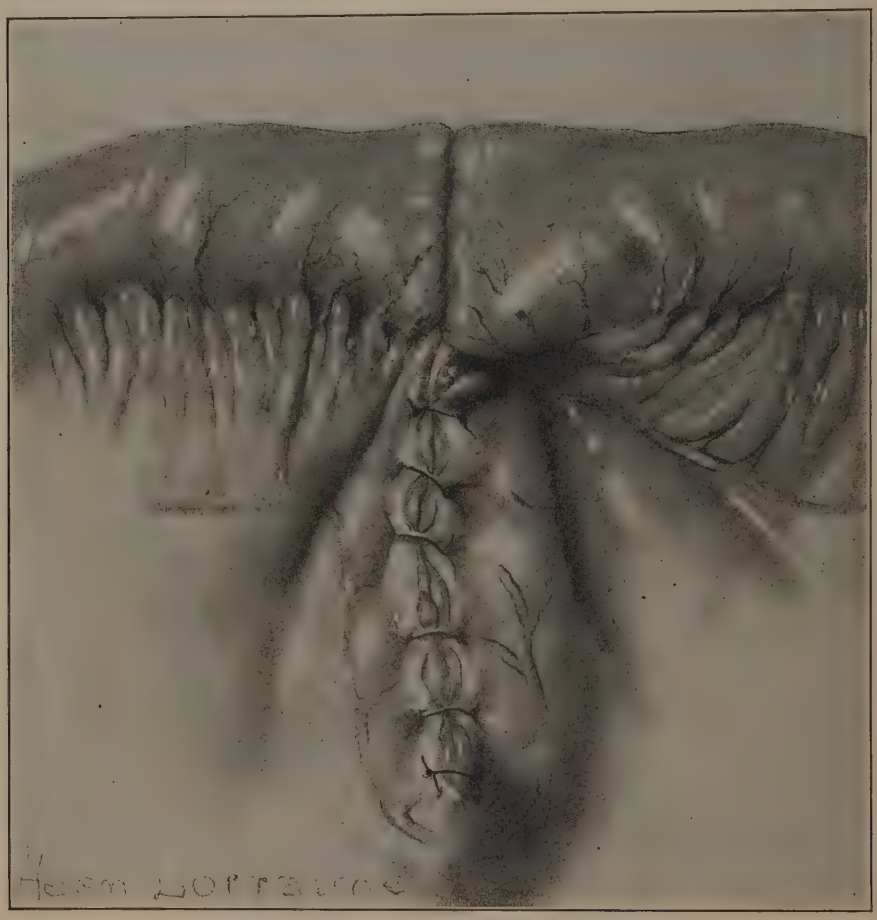

FIG. 138.—RESECTION OF THE JEJUNUM.

When the suturing of the bowel has been completed, almost none of the thread shows on the surface. Due to the somewhat oblique manner in which the resection is made the lumen at the line of suture is not diminished. The wound in the mesentery is united with a continuous suture of plain catgut.

knot of the second suture. The short ends can be readily manipulated by the Grant, or a similar method of tying the short end.

When the anastomosis is complete it will be found that the gap in the mesentery has been greatly diminished. The wound in the mesentery is closed by a continuous suture of plain catgut (Fig. 138). If the mesentery contains much fat this suture should be applied on each side. If it is thin, the suture includes the whole thickness. Care must be taken to avoid wound-

ing the vessels or including any of the arteries in this suture, which might seriously imperil the nutrition of the bowel ends. If the bowel is markedly dilated above the resection, it would be best to add an enterostomy on the oral side of the resection about 8 to 12 inches (20.3 to 30.5 cm.) from the union (Fig. 139).

If the resection is in the lower ileum or involves the cecum, different physiologic and anatomic problems are involved, which have already been discussed. The size of the lumen, while important, is not so vital here as in the upper jejunum, but every care should be taken to avoid soiling the surrounding tissue with the intestinal contents which contain an abundance of

FIG. 139.—SPECIMEN OF SMALL BOWEL WITH LARGE FISTULOUS OPENING.
The specimen was removed and the bowel was united according to the technic described.

bacteria of great virulence for establishing peritonitis. The loop of bowel should be prepared as in the resection of the upper jejunum, the mesentery being doubly clamped, divided and tied in sections, and the triangular space at the mesenteric border of the bowel occluded. The technic evolved by Kerr and Parker seems to fit the indications for resection in this region better than the technic that has just been described, because in the Kerr technic the lumen of the bowel is not so exposed that the mucosa or the intestinal contents can contaminate with sepsis. While the lumen is not so wide nor the bowel so accurately sutured in the Kerr resection, it is not essential to secure a wide lumen in the ileum as in the upper jejunum. A sufficient opening can usually be provided by the steps of this technic. It should not be used, however, if there is excessive fat in the mesentery.

No soft-bladed intestinal clamps are used. The bowel is clamped, somewhat obliquely from the mesenteric border outward toward the healthy bowel, at the line of proposed resection with an ordinary straight pedicle forceps, as the Ochsner forceps, and close to this is applied a clamp with rather small

blades. A small Payr crushing clamp is useful. The clamps devised by Barr, of Nashville, are particularly suited for this operation if the bowel is not too large and bulky, when a Payr clamp should be used. The Barr clamp has a narrow blade and secures a very satisfactory hold, but has not the strength of the Payr clamp which is necessary in bulky fat tissue. The clamp and the pedicle forceps should be as close together as possible (Fig. 140). The Payr or the Barr clamp is placed on the healthy side of the proposed line of resection. If the mesentery is fat it should be stripped back from the clamp for

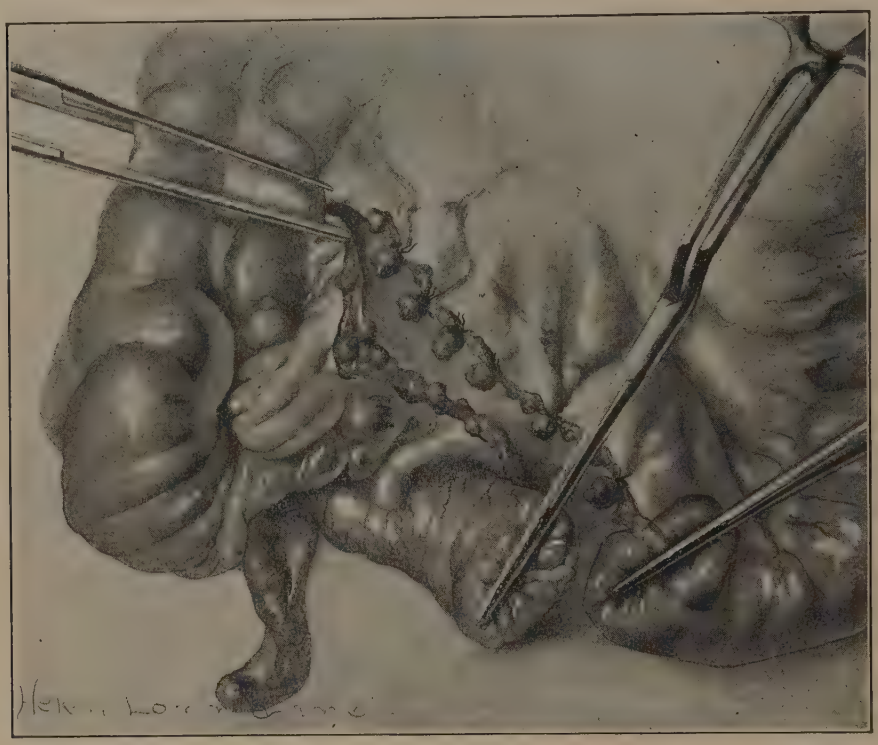

FIG. 140.—KERR RESECTION OF THE LOWER ILEUM AND CECUM.

The mesentery has been divided and tied in sections. The Barr clamps are shown in the drawing. Either they or small Payr clamps may be used. The clamps at the two ends of the affected loop are placed in different planes. One end of the bowel has been divided with the electric cautery.

about a half inch (1¼ cm.). Better still, the bowel may be prepared in this way before placing the clamp. This exposes the intestinal wall for accurate suturing which may otherwise be difficult on account of the fat. Much of the end of the bowel is inverted and the sutured portion is sufficiently near the well-nourished area. The bowel is divided between the clamp and the pedicle forceps with an electric cautery, the surrounding tissue having been thoroughly protected with moist gauze. The tissue within the grasp of the clamp on the healthy end of the bowel is severed flush with the clamp. In this way no septic matter is exposed (Fig. 141). The other end of the bowel is treated in a similar manner, except that the clamps should be applied

in a different plane on the two ends so that when they come together the triangular mesenteric spaces will not be opposite each other.

The stumps are temporarily closed with a basting stitch of linen or silk. It is begun at the portion of the bowel near the heel of the clamp. The first stitch is taken parallel with the axis of the bowel and on the margin of the clamped portion so that it will lift up this part of the bowel and tuck in the end of the stump when the clamp is released and the basting stitch is tightened.

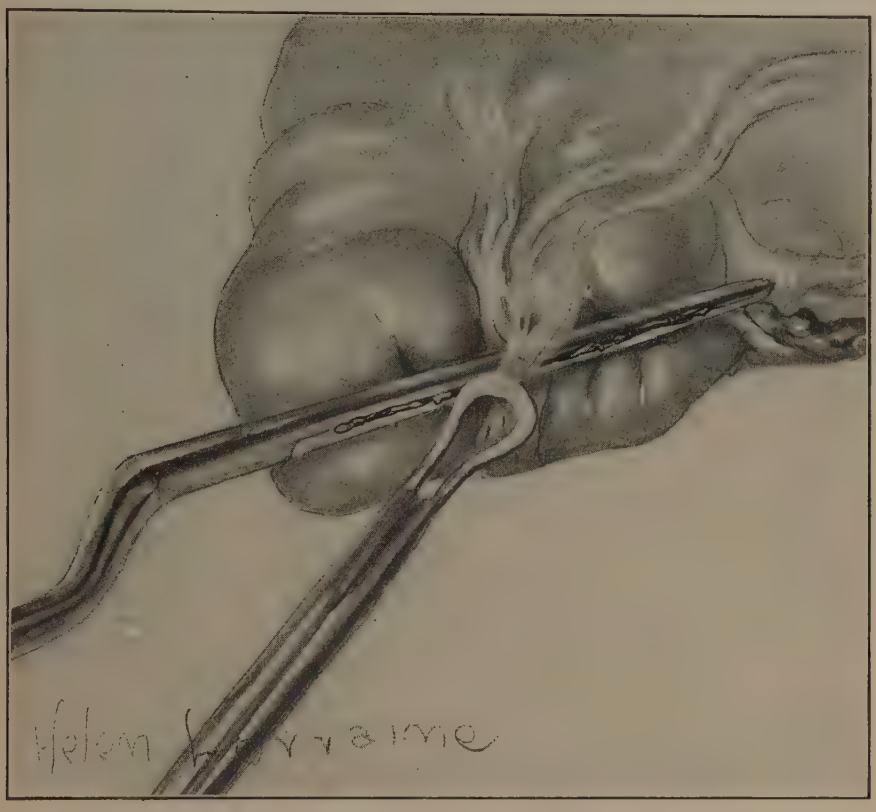

FIG. 141.—KERR RESECTION OF THE LOWER ILEUM AND CECUM.
The stump of the bowel included in the clamp is thoroughly cauterized until it is flush with the clamp.

The next bite is on the opposite side of the clamp and is close to the clamp and placed after the manner of a right-angle continuous or basting stitch. The suture then crosses to the other side of the clamp (Fig. 142), and is continued back and forth until the other end of the stump of the bowel is reached. The last bite of suture is taken in the reverse direction of the first stitch, being in the axis of the bowel with the point of the needle directed away from the clamp so that the general effect of the last stitch is the same as of the first. It will thus lift up this part of the bowel and securely tuck in this end of the stump.

When the material is bulky, and especially if there is much fat, it may

FIG. 142.—KERR RESECTION OF THE LOWER ILEUM AND CECUM.

The basting stitch is applied on both the stumps of the bowel after the manner shown in the illustration. The frrst suture begins at some distance from the clamp and is taken in the direction of the axis of the bowel. The others are parallel with the clamp. The last suture is also taken in the direction of the axis of the bowel at right angles to the clamp. A small loop of linen or catgut is placed under the basting stitch about its middle, in order to facilitate the subsequent withdrawal of the basting stitch.

FIG. 143.—KERR RESECTION OF THE LOWER ILEUM AND CECUM.

The two ends of the basting thread are caught with sutures and held taut in the axis of the line of suturing while the clamp is gradually loosened and withdrawn. This automatically inverts the stump of the bowel.

be difficult to withdraw this basting stitch, so I use a slight modification of the Kerr technic by placing a loop of small linen, silk, or catgut under one of the loops of the basting stitch about the middle of the line of sutures. This is clamped but not tied (Fig. 142). A similar procedure is repeated on the other end of the bowel.

FIG. 144.—KERR RESECTION OF THE LOWER ILEUM AND CECUM.

The two ends of the bowel are brought together and united with a continuous right-angle suture of linen or silk, taking an occasional backstitch. When the end of the ileum is joined to the end of the colon, as shown in the illustration, the line of sutures is about an inch from the end of the ileum in order to produce invagination and simulate the ileocecal valve.

When the basting stitch has been applied on both ends, the first stump of the bowel is taken up and sharp-nosed hemostats grasp the ends of the basting stitch close to the bowel. Traction is made on these ends in a straight line opposite to each other, and in the general axis of the line of sutures. While this tension is continued the clamp is gradually loosened and withdrawn, and the basting thread will tighten, and as it closes down will automatically invert the small crushed ribbon consisting of the end of the bowel which has been within the grasp of the clamp. This ribbon adheres sufficiently firmly

to prevent opening during the withdrawal of the clamp, so the stump is aseptically sealed. A new grasp is caught on the basting thread close to the bowel. The traction should be constantly maintained in the axis of the line of sutures. If the basting thread is bent or the tissues pushed in from either end, it will have somewhat the effect of a purse-string suture and obstruction may result (Fig. 143). It is important, then, that traction be maintained at the proper axis and that the tissues be not drawn together in a central mass.

Fig. 145.—Kerr Resection of the Lower Ileum and Cecum.

When the suturing is completed traction is made on the basting thread at either end and the thread is withdrawn. If for any reason it hangs, it is pulled up by the loop of linen or catgut that was originally placed under each basting stitch. This additional precaution insures the removal of the basting stitch.

The two ends of the bowel having been thus treated are brought together and united with a continuous mattress suture of linen or silk (Figs. 144, 146). At intervals of every third or fourth stitch a backstitch is taken to lock the suture. The posterior surfaces are first sutured snugly together and each stitch should catch a sufficient depth to hold firmly. The suture can probably best be applied with a curved needle. The triangular space which has been clamped and tied may be disregarded because the application of the crushing clamps has placed these spaces in such a position that they will not be apposed to each other. When the ends of the basting stitch have been reached the suture is continued anteriorly as close as possible to the basting stitch and

FIG. 146.—KERR RESECTION OF THE LOWER ILEUM.

The previous illustrations have shown the technic of Kerr applied to resection of the lower ileum and cecum. When applied solely to the ileum, the technic differs only in not arranging for invagination of an end of the bowel, but in uniting both ends close to the basting stitch.

is tied at the original end. If the tissues are thick or fat, interrupted mattress sutures may be used, especially posteriorly. The basting stitches are cut short at one end, and the other ends are slowly withdrawn, making traction in the axis of the thread. If for any reason they do not pull out readily, as sometimes happens in thick fatty tissue, the loops of thread placed in position and clamped when the basting stitch was inserted, are pulled upon sufficiently

to draw the basting stitch to the surface, where it may be either divided with scissors or pulled out (Fig. 145). If the basting stitch comes away without any difficulty the loops of thread are easily removed. If there is any weak spot after removing the basting threads, an additional suture may be applied, but care should be taken to use no more sutures than may be necessary. The wound in the mesentery is united as described in the previous operation.

After all sutures have been applied the finger and thumb of the right hand catch the bowel on each side of the union and invert it so as to separate the thin ribbon of the crushed bowel which is probably still adherent. The operator should be satisfied that he has separated this agglutinated ribbon of the stumps of the intestine, or there may be obstruction.

The cecum can be excised with the terminal ileum by using this technic. The only changes are that it may be necessary to pucker the basting thread on the stump of the ascending colon so as to reduce the surface to the size of the stump of the ileum. Then, too, in order to simulate the ileocecal valve I have made a practice of applying the suture to the iliac stump about an inch (2.5 cm.) from the end of the ileum, and as close as possible to the inverted basting thread on the stump of the colon. In this way the invaginated ileum protrudes into the colon and when the basting threads are withdrawn and the agglutinated margins are separated with the finger and thumb, the end of the ileum acts somewhat as an ileocecal valve and prevents a free reflux of the colonic contents into the ileum. Kellogg has laid considerable emphasis on the importance of the function of the ileocecal valve in preventing back pressure. That such a reconstructed ileocecal valve will function in preventing back pressure is shown in two of our cases in which roentgenographic studies were made a few months after excision of the terminal ileum and cecum. This invagination, particularly if there is much fat, is also an additional security against leakage.

The advantages of this technic have already been indicated as avoiding contamination with the fecal contents. An additional advantage is that the crushed margins of the ends of the bowel which are turned in by the basting stitch are charred and sterile and act as a seal over the underlying tissue, much as the eschar after a clamp and cautery operation for hemorrhoids. The power for absorption of the raw cut margin is doubtless considerable, and when the contents of the bowel are septic and toxic, as in the ileum and colon, this raw surface probably becomes infected and acts as an open portal for bacteria.

With the use of the Kerr technic, however, this avenue is sealed and granulation tissue forms beneath the charred margin. When the eschar separates a few days later the granulating surface is less likely to be a focus for absorption than would be freshly cut tissue. After a few days, too, when this granulating area is exposed, the peritoneal surface has become firmly adherent and even if infection should occur, it would be much more likely to be limited to the intestinal margins than if it took place in the freshly cut bowel before the peritoneal union had become firm.

**Lateral Anastomosis.**—Lateral anastomosis is indicated when there is a large amount of fat in the mesentery of the lower small intestine or a diminished caliber of the bowel. The smaller rate of absorption and the decreased muscular activity in the lower ileum as compared with the upper jejunum make a variation from the normal axis of the bowel more readily tolerated in the ileum. Excessive fat in the mesentery renders it difficult to suture the bowel accurately in the Kerr technic. Though the triangular spaces at the mesenteric borders are not apposed to each other, intestinal sutures that must penetrate much fat, even on one side, before reaching the bowel wall are not safe. The healing of fat under pressure of the sutures is uncertain. The fat may break down and cause leakage. With a very fat mesentery lateral anastomosis should be done. If the stumps of the bowel are properly sealed, infection of the mesenteric fat is avoided and the dangers from contamination along the smooth peritoneum at the lateral anastomosis are much less than at the mesenteric spaces.

The loop of bowel to be resected is prepared by severing and tying the mesentery and closing the triangular mesenteric space as indicated in the end-to-end resection. It is best to sever the bowel according to the Kerr technic, turning in the ends with a basting stitch. Instead of withdrawing the basting stitch, however, it is used as a gathering suture, the bowel is puckered, and the two ends of the basting stitch are tied together. This should be reinforced by a purse-string suture which will bury the knot of the original basting stitch. So far the lumen of the bowel has not been exposed, and as the indications for this operation are chiefly in the lower ileum, the carrying out of a technic which as far as possible will avoid exposure of the lumen of the bowel is important.

The fecal contents are stripped out of each bowel end for about 4 inches (10.2 cm.) and soft-bladed intestinal clamps are applied. In the absence of a soft-bladed clamp a tape may be passed through the mesentery and tied just snugly enough to occlude the bowel without being tight enough to injure it; or any of the usual substitutes may be used, such as penetrating the mesentery with hemostatic forceps, catching a band of rubber in the tip of the forceps and wrapping the other end of the band over the handle of the forceps, so compressing the bowel on the clamp. Usually these substitutes are not necessary, because soft-bladed intestinal clamps are available. The ends of the bowel are laid side by side for a distance of about 3 inches (7.7 cm.) with the ends pointing in opposite directions, and are sutured together with a continuous right-angle suture of linen or silk, with a backstitch taken at intervals. The intestine is carefully surrounded with moist gauze, and every precaution is taken to prevent soiling of the tissues with the fecal contents.

An incision is made in one of the limbs of the bowel about one-third inch (0.8 cm.) from the line of sutures, the sutures having been placed in such a way that the incision shall be through the convex border of the bowel opposite the mesenteric attachment. This incision is made slowly and the bowel contents are gently removed with moist sponges. Any undue rough handling

will not only injure the tissues, but will tend to force into the raw surface the septic fecal matter. After the incision has been made for about two and a half inches (6.3 cm.), the stump, back to the intestinal clamp, is cleaned with strips of moist gauze and packed with moist gauze. Some antiseptic solution, as iodid of mercury solution, is satisfactory, and if not too strong will have no deleterious effect. It is probable that sterile salt solution will be almost as

FIG. 147.—LATERAL ANASTOMOSIS.

The bowel has been resected and the stumps have been treated as described in the text. The sides of the intestinal ends are united with a line of sutures. Incisions are made and carried well down to the end of each stump, and the bowel is sutured after the manner of a gastro-enterostomy.

efficacious, though a weak antiseptic that does not damage the tissues seems better.

When the incision in one end of the bowel has been made and the bowel has been properly prepared, the other end is incised and treated in a similar manner. It is essential to see that the cut goes well to the inverted stump, particularly on the oral side, because fecal contents will collect at this point if a culdesac is left. This is one of the chief objections to lateral anastomosis. After the incisions have been completed and the bleeding points clamped, the

two margins of the wounds in the intestine are united with a continuous lockstitch of fine tanned catgut. This is carried anteriorly as in gastro-enterostomy and continued as a lockstitch, catching only a small bite with each insertion of the needle so as to avoid leaving a large bulk of tissue to be covered by the outer row of sutures. No effort is made to invert with this line of sutures. The suture is terminated by tying it to the end left from its original knot and is cut short. The site of the sutures is sponged with moist gauze and the original outer row of linen or silk is continued around as in gastro-enterostomy, using a right-angle continuous suture with occasional backstitches and tying the thread at the short end of the suture left when the original knot was made (Fig. 147). An additional interrupted stitch of linen or silk may fasten the end of the bowel to the side of the adjoining intestine, but this is usually not necessary if the incisions have been carried sufficiently far to the bowel ends.

**Enterostomy.**—The operation of enterostomy is often an emergency operation, and is frequently life-saving. Its indications are somewhat variable, and while it should not be substituted for a more radical procedure when there is strangulated or gangrenous bowel, it is strongly indicated in post-operative obstruction, which is frequently due to lymphatic adhesions or kinks, and in obstruction due to cancer of the colon. There are several types of enterostomy, the operation to be used depending to some extent upon the local conditions.

In inoperable cancer of the right colon or in ulcerative colitis, where it is desired to give complete rest to the colon, the lower ileum is brought into the wound and completely divided. This operation was practiced by the late John Young Brown, of St. Louis, for giving physiologic rest to the large bowel. The chief objection to it is that it often impairs the general metabolism by interfering with the absorption of water. If there is a complete division of the lower ileum and a diversion of all the fecal contents, the most important area for absorption of water, the cecum and right colon, is deprived of this function.

The complete enterostomy of Brown may be done through a muscle-splitting incision as for appendicitis. If it is desirable to make an exploration, in a thin individual this incision may be enlarged, or a right rectus incision be made. The kind of incision, then, may depend upon the condition of the patient and the desirability of a complete exploration. In the original Brown operation the section of the ileum was made so close to the ileocecal valve that if reconstruction of the continuity of the bowel was later indicated it would be necessary to make a lateral or an end-to-side anastomosis of the ileum to the colon. This, however, may be avoided by dividing the ileum about 6 or 8 inches (15.3 or 20.3 cm.) above the ileocecal valve, so that if a period of rest of a few months results in cure of the colonic lesion the continuity of the ileum can be established by an end-to-end union of the ileum and the structure of the ileocecal valve will be preserved. This is a point of some little importance in cases in which there had been extensive ulcerative colitis, for it will protect the small bowel from the back-flow

of the large intestine and will result in a more physiologic condition as to the emptying of the contents of the small bowel into the cecum and colon.

The lower ileum is identified by the ileocecal valve and the ileocecal fold. A segment of the bowel about 6 to 8 inches (15.3 to 20.3 cm.) from the ileocecal valve is brought into the wound and packed around with gauze. The mesentery is incised from the bowel downward for a distance of about 3 inches (7.7 cm.). The bleeding vessels are clamped and the incision is carried to the bowel through the triangular mesenteric space, which is clamped and tied as in resection of the bowel. After ligating all bleeding points the contents of this loop are stripped for a distance of about 3 inches (7.7 cm.) on each side of the incised mesentery, and a soft-bladed intestinal clamp is applied. Moist gauze is placed through the divided mesentery and every effort is made to protect the surrounding tissue. The bowel is clamped by two Ochsner or straight pedicle forceps placed as close together as possible and divided with the electric cautery. If the operation is done for ulcerative colitis and it is intended as an after-treatment to irrigate the colon, a large soft rubber catheter may be placed in the lower end of the bowel. There should be several additional perforations in the catheter, and it should be long enough to go through the ileocecal valve and to allow the tip to rest within the cavity of the cecum. A purse-string suture of silk or linen is inserted while the clamp is in position, the pedicle forceps clamp is removed, the catheter introduced into the distal end of the bowel to the proper length, and the purse-string suture is tied snugly around the catheter. The intestinal clamp is loosened and removed as the catheter is being introduced. An end of the purse-string suture is passed through the wall of the catheter and again tied so as to hold the catheter in position. If the purse-string suture is placed close to the end of the bowel the margin of the bowel cannot well be inverted. A second purse-string suture is inserted while pushing the catheter a little further in. This covers the original purse-string suture and provides a peritoneal coat at the end of the bowel.

The upper end, which in the meantime has remained clamped, may be treated according to the indications. It would probably be somewhat safer, so far as infection is concerned, to leave the clamp in position for twenty-four or forty-eight hours until the surrounding tissues and the peritoneum have become adherent. An obstruction here for this length of time without damaged intestine can usually be readily borne by the patient; but if care is taken to avoid spilling the fecal contents, the operation may be completed. The lower end of the bowel in which the catheter has been inserted is fastened to the peritoneum by a few sutures of catgut. The upper (oral) end is brought out for about 2 inches (5 cm.), and its mesentery is sutured to the parietal peritoneum. The intestinal clamp that was placed originally 4 inches (10.2 cm.) from the point of section, is moved down 2 inches (5 cm.). A purse-string suture is inserted as was done in the distal end, and a large catheter having several perforations near the end, or a small rectal tube, is quickly introduced after the pedicle clamp has been removed. The purse-string suture is tied snugly around the tube, and an end of this suture

transfixes the wall of the tube and is tied. The intestinal clamp is removed and the catheter is adjusted (Fig. 148). There is no occasion for applying a second purse-string suture. After suturing its peritoneal coat to the parietal

FIG. 148.—THE JOHN YOUNG BROWN ENTEROSTOMY.

A medium-size soft rubber catheter has been introduced into the distal end and fixed with a purse-string suture, and is being buried with a second purse-string suture. A larger tube is applied in the oral end of the bowel where no effort is made to invert the peritoneum.

peritoneum the upper end of the bowel is left protruding about an inch (2.5 cm.) above the level of the skin. If the patient is fat and the parietal peritoneum is difficult of access, the bowel is sutured to the subcuticular fat and

fascia. The end of the bowel is packed around with iodoform gauze. By taking these precautions there is but little danger of soiling the tissues in the wound. The catheter in the lower end of the bowel is kept clamped except when medication or irrigation is to be applied to the colon. The tube in the upper end of the bowel is connected with a bottle, and the fecal contents are drained off. This upper tube will stay in place for several days, until the tissues of the surrounding wound have had an opportunity to form granulations and become resistant to the septic material of the fecal contents. Peristalsis will tend to force out this tube after a few days, and the wound must then be treated as an artificial anus.

In the lower end, however, in which there has been inversion and a peritoneal coat around the stump of the bowel, the tube will remain indefinitely, and at the same time serves as a plug to prevent fecal matter gaining access to the colon. If it is desirable, the lower tube can be removed and the bowel sutured, or it will close readily without suturing if a sufficient amount of the end has been inverted. If the colonic lesion clears up the reëstablishment of the continuity of the bowel after this enterostomy becomes a matter of resection, but there should be no effort at such reëstablishment until several months after the colon has apparently fully recovered its normal state.

If the enterostomy is to be closed, the patient is given sterile food for several days before operation. The wound, of course, is kept clean. Immediately before the operation the upper end of the bowel is packed lightly with moist gauze. The incision is carried down in such a way that the free peritoneal cavity is opened and will give access to the ileum a few inches from the enterostomy on its oral side. A soft-bladed intestinal forceps is placed at this point, and the adhesions around the artificial anus are detached with the fingers, working from within outward. After this end has been mobilized, the distal stump is brought into the wound, the two ends are clamped as in the Kerr operation, and union is made by that technic (page 279).

In postoperative intestinal obstruction, and also as an adjuvant operation in resection of the bowel when there is dilatation of the oral portion of the intestine, a small opening and the insertion of a soft rubber catheter of medium size, is all that is necessary. Here the excessive peristalsis, the increased intestinal pressure, and the late exhaustion of the muscle from excessive peristalsis, derange the motive forces of the intestine and may cause absorption of some retained toxic material. The contents of the small intestine are always liquid and can be removed just as satisfactorily through a medium-size catheter as through a large drainage tube or an open incision in which the bowel content is permitted to flow over the abdominal wound. An open enterostomy that permits fecal matter to flow over the raw surface of the abdominal wound should never be done as a primary procedure, for even when the bowel must eventually be opened, it is best to insert a catheter for a few days until satisfactory adhesions have developed around the loop of intestine.

When the indications are for a tube enterostomy, and not for a complete diversion of all the fecal contents, the most satisfactory operation in my practice has been an indirect insertion of a rubber catheter, using the principle of

Coffey. Coffey has demonstrated that in the transplantation of ducts, such as the bile duct or the ureter, the insertion should be made in an oblique manner, so that the mucous membrane of the receptacle acts as a valve and prevents back-pressure into the duct when the viscus into which it empties is distended. This principle has been mentioned in the description of the operation for implantation of the common bile duct after excision of the duodenum. In enterostomy in very ill patients a small incision is made, preferably a muscle-splitting incision, in the right iliac fossa; for if there is doubt as to where the obstruction is an incision in the right iliac fossa should be made. This is done under local anesthesia. When the point of obstruction can be localized, the intestine should be exposed as near the obstruction as possible.

Lee and Downes have called attention to the advantages of making an enterostomy high in the small intestine. This relieves the pressure in the upper bowel where obstruction seems to be rapidly fatal, but if the enterostomy can be placed near the obstruction, naturally more of the distended bowel will be emptied by normal peristalsis. In several instances, I have found that after making an enterostomy close to the obstructed loop a secondary obstruction would occur higher up, and it would be necessary to do another enterostomy. It seems better, however, to do this occasionally than to perform a high enterostomy in each case, as there is always a danger of malnutrition with a high enterostomy that would not obtain lower in the intestinal tract.

The loop of bowel is exposed and, if possible, brought into the wound. This should be done gently. The bowel must not be caught with stout forceps or with heavy crushing clamps, as it will easily tear when distended, and flooding of the field with fecal matter might be disastrous. In acute obstruction, however, when there is much free fluid in the peritoneal cavity, and a marked hyperemia, the resistance to infection is very great. The spilling of a small amount of fecal matter under these conditions would probably have but little effect. Care should be taken, nevertheless, to avoid such an accident. If the operation is done for a postoperative obstruction, the nature of the free fluid in the abdomen is not of the same significance as if it were done for an obstruction whose cause is not definitely known. If there has been no preceding operation and the free fluid is blood-tinged, it seems to indicate that there is a strangulation or volvulus, or thrombosis, and in such instances no matter how desperate the risk, it is essential to discover the cause of the obstruction, and to remove any bowel that may be gangrenous. The intravenous injection of 5 per cent glucose, as practiced by Matas, of New Orleans, and the transfusion of blood, may often overcome shock and permit operations to be performed successfully that were formerly considered unjustifiable. Concentrated salt solution, too, in these cases has been found to be very beneficial. These matters are discussed more fully in the chapter on obstruction.

After opening the abdomen if the indications show that there is no strangulation, volvulus or mesenteric thrombosis, the operation is proceeded with by carefully delivering and clamping transversely a loop of bowel with long

soft-bladed intestinal forceps after milking out as much of the contents as possible. The bowel is packed around with moist gauze, and an incision about 2 inches (5 cm.) long is made with a sharp knift through the peritoneal and muscular coats down to the mucosa. Even in a dilated bowel this can usually be done if the knife is sharp, and if a sliding and pushing

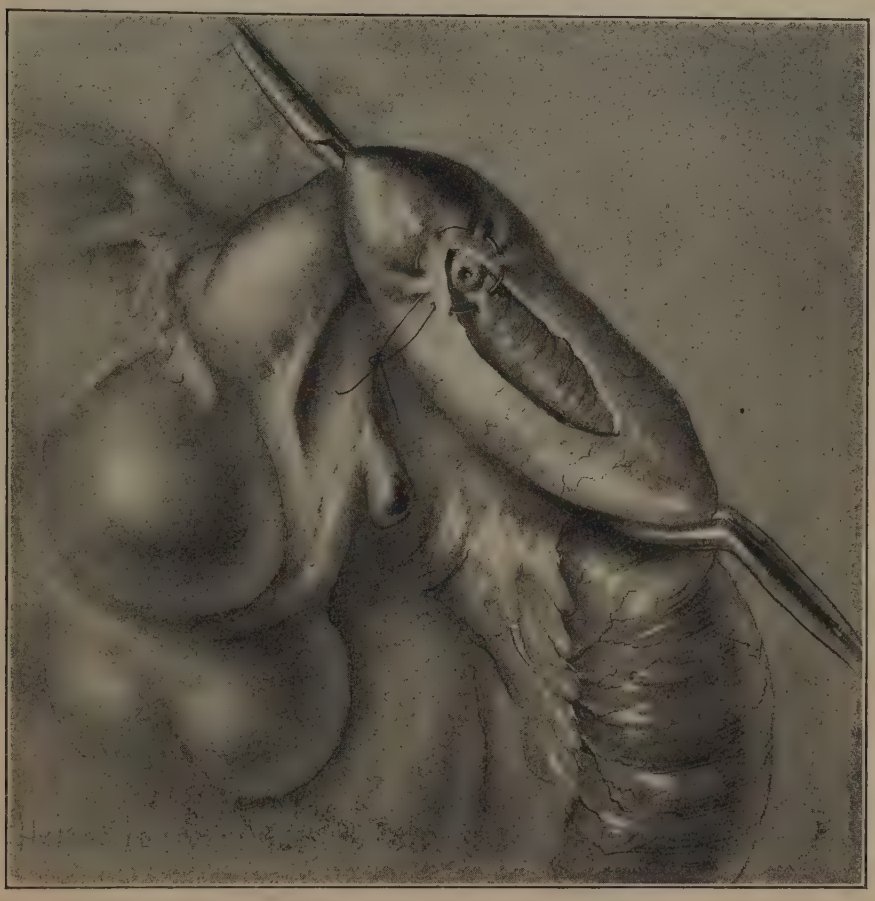

FIG. 149.—ENTEROSTOMY, USING THE PRINCIPLE OF COFFEY.

The bowel is delivered into the wound and clamped, either with a long Stille clamp or else with two soft-bladed clamps as used for lateral blood-vessel suturing. An incision about two inches long is made with a sharp knife down to, but not through, the mucosa. The mucosa is exposed by gently dissecting away the muscular coat. A purse-string suture is inserted, preferably at the distal end of the incision, and the mucosa is punctured with a sharp-pointed knife. A previously prepared catheter is inserted.

stroke is used instead of a straight cutting stroke. In this way the peritoneal and muscular coats are dissected and pushed from the mucosa over the length of the 2-inch (5 cm.) incision for a width of about a half inch (1.3 cm.). At one end of this incision, preferably the distal end (though it is of no great importance in obstruction), a purse-string suture of linen is inserted (Fig. 149). The first loop of the knot is made loosely, and the two ends

are held by the operator. At one or two other points the purse-string is caught with mosquito forceps and held up. The exposed mucosa within the

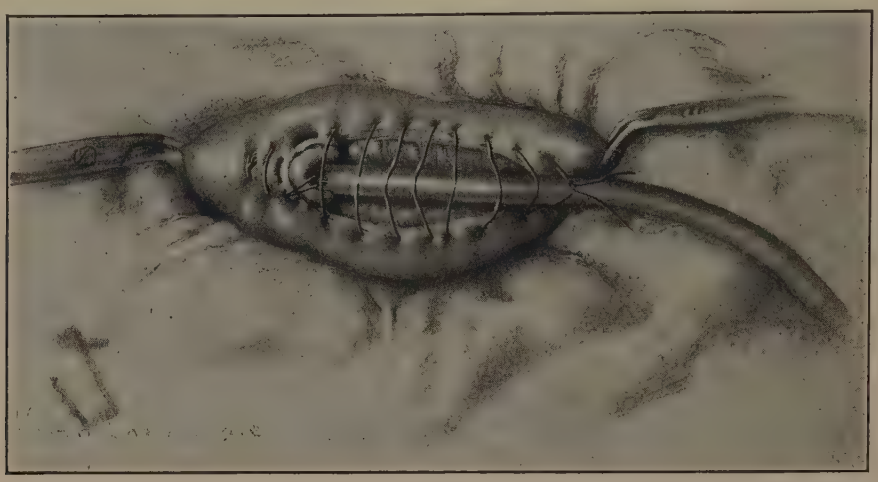

FIG. 150.—THE PURSE-STRING SUTURE IS TIED SNUGLY AROUND THE CATHETER AND ONE END IS PASSED THROUGH THE CATHETER AND AGAIN TIED. THE CATHETER IS LAID UPON THE MUCOSA AND SUTURED IN THIS POSITION.

grasp of the purse-string suture is punctured with a sharp-pointed knife, and a medium-sized soft rubber catheter in which two additional perforations have been made is inserted through this puncture. The purse-string suture

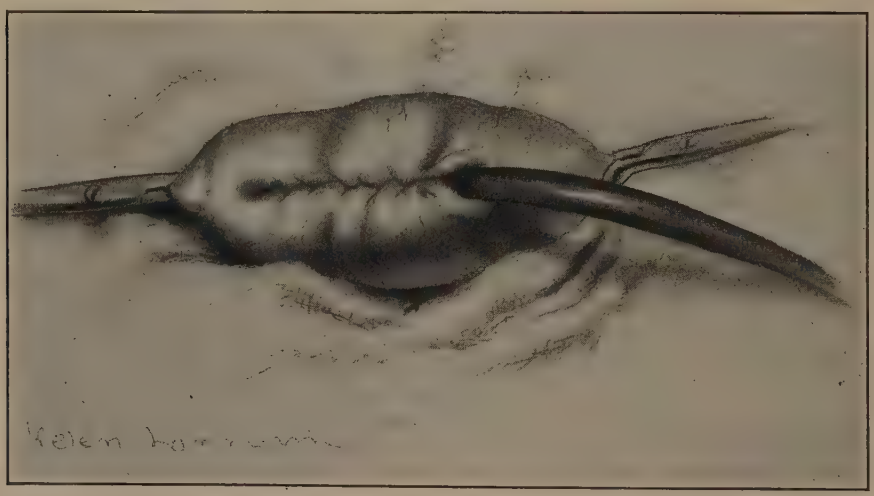

FIG. 151.—THE SUTURES, WHICH ARE CONTINUOUS RIGHT-ANGLE SUTURES OF LINEN OR SILK, BURY THE CATHETER.

is snugly tied around the catheter and an end of the suture transfixes the catheter and is again tied. This holds the catheter firmly in position. It always cuts loose, however, within five to ten days, and there is no difficulty about the catheter being removed. The catheter is laid upon the exposed

mucosa, and covered with a row of linen sutures applied as a continuous right-angle suture (Fig. 150). In some instances it may be necessary to apply two rows of sutures, but usually one is all that is required unless the bowel wall is very thick and friable (Figs. 151, 152). The intestinal clamp is removed and the end of the catheter in the bowel is adjusted so it is not kinked.

The loop of bowel is returned within the abdominal cavity. If there is omentum in the neighborhood it is stitched around the catheter and over the

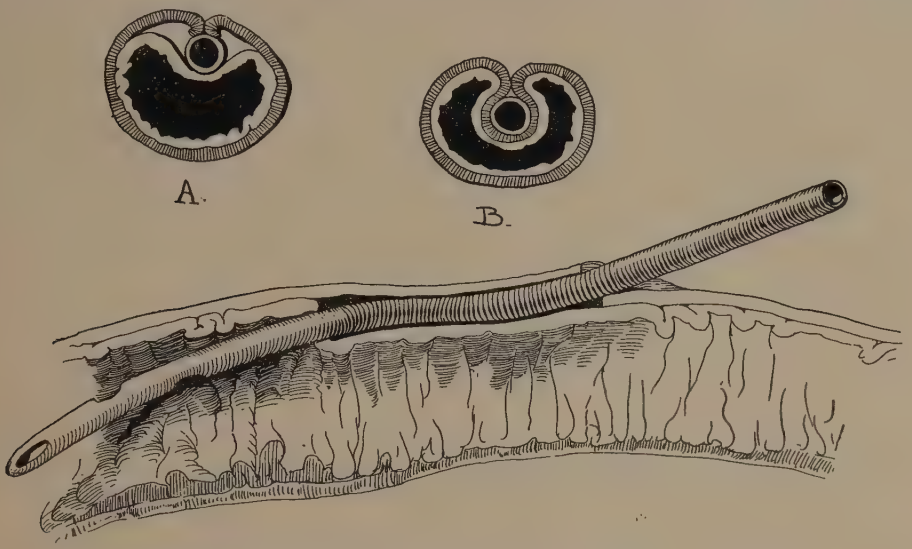


FIG. 152.—A LONGITUDINAL AND A TRANSVERSE SECTION SHOWING THE RELATION OF THE ENTEROSTOMY TUBE TO THE MUCOSA.

In the longitudinal section the catheter rests on the mucosa which acts as a valve. In A is seen the transverse section of this enterostomy. Note the relatively small impingement of the tube on the lumen of the bowel and the absence of peritoneum lining the tunnel in which the catheter rests. B shows a transverse section of enterostomy after the method of Witzel. There is greater impingement on the lumen of the bowel and the tunnel is lined with peritoneum which tends to throw out lymph and make a rigid tube.

enterostomy wound, though this is not essential, and it is best not to make any prolonged hunt for the omentum. If no omentum is present the bowel where the catheter emerges is fastened to the parietal peritoneum with a single suture of 00 tanned catgut. The rest of the wound is closed rather snugly around the catheter, all of the bowel being within the peritoneal cavity. Just beyond the skin level a strip of zinc oxid adhesive plaster is wrapped around the catheter and a suture is placed from the skin into the adhesive plaster. In this way the strain is taken from the suture that fastens the catheter to the wall of the intestine, and it can be kept in place much longer than if dependence is placed solely upon the suture in the intestinal wall. Besides, sudden jerking or undue traction might displace it too soon and result in flooding the wound with fecal contents. The end of the catheter is placed in a pus basin until connected with a bottle by the side of the patient's bed.

The catheter comes away readily, or can be removed at the end of a week. In most of the cases the valve of mucosa is so efficient that no fecal contents leak out, and only some seropus discharges for a while. In some cases, however, a discharge of fecal matter may persist for a few days; but even this is much better than having fecal drainage following practically every case.

Whenever the bowel is resected and there is considerable distention above the lesion, it is always well to do this enterostomy. If the operation is done as an adjuvant to intestinal resection, some slight modification of this technic is advisable. The catheter is first introduced through a stab wound to one side of the abdominal incision through which the resection was made. The distal end is clamped, and the enterostomy is then done as has been described. The loop of bowel in which the enterostomy exists is brought snugly to the parietal peritoneum and sutured in that position. If the catheter were first sutured in the bowel and then passed through the stab wound there would be an opportunity for infection of the stab wound. This enterostomy should be done about 6 to 8 inches (15.3 to 20.3 cm.) from the point of resection, and never next to the resection. If in immediate proximity it may cause excessive adhesions and a kink at the line of union.

This operation may be done without making the incision down to the mucosa, merely turning in the whole wall of the bowel after the method of Witzel. When the bowel is greatly distended and thin, such a technic is useful, but the exposure of the mucosa after the principle of Coffey, as has been outlined, has several advantages. First of all, it does not encroach quite so much upon the lumen of the bowel as when the whole thickness of the intestinal wall is invaginated. This, of course, is of no importance when the bowel is dilated and large, but after contraction occurs it may be of some moment. Another disadvantage of the Witzel method is that when the whole thickness of the bowel wall is utilized the lining of this new channel is formed by the peritoneum. Peritoneum when irritated pours out lymph which becomes firm. This constitutes a rigid tube that will not readily collapse. Submucous tissue does not pour out such large quantities of lymph as the peritoneum does, and the mucosa is more pliable and will more readily act as a valve after the catheter has been withdrawn. Pressure within the intestine closes this valve, which preserves much of the mobility of the mucosa. A tube formed of all of the coats of the bowel in which the inner lining coat is peritoneum is comparatively rigid and closes more slowly.

In certain types of postoperative obstruction when it is difficult or impossible on account of adhesions and distention to deliver a loop of bowel into the wound, and when sutures cannot be readily applied, the operation of J. W. Long is satisfactory. In postoperative obstruction Long removes one or two stitches of the wound and without making any effort to search for the point of obstruction the first distended coil of bowel is exposed as well as possible. A purse-string suture of silk or linen is placed, catching a firm grasp in the wall of the bowel and encircling a space about a half inch (1.3 cm.) in diameter. The suture is caught at two points with forceps and the untied

ends are held with the fingers. Making traction on the forceps and on the ends of the suture elevates the wall of the bowel and steadies it. The surrounding tissues are packed off with moist gauze. While the ends of the suture and the two hemostats on the loops of the suture are held taut, the center of the area enclosed by the purse-string suture is perforated with the cautery (Fig. 153). The cautery not only sterilizes the opening, but tends to seal the coats of the intestine and to prevent the eversion of the mucosa which often occurs after an incised wound. A previously prepared rubber tube, such as a soft rubber catheter, which is larger than the perforation in the bowel, is introduced with forceps, so the tube fits into the bowel snugly. The forceps

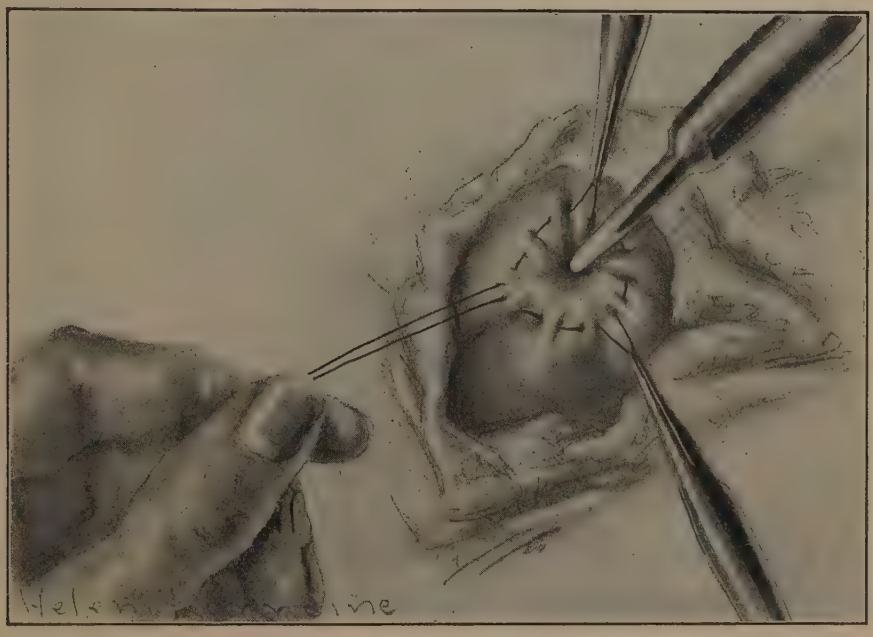

FIG. 153.—THE J. W. LONG METHOD OF ENTEROSTOMY.
A purse-string suture has been applied and the cautery is perforating the bowel within the grasp of the purse-string suture.

is then removed and the purse-string suture is tied. This inverts the edges of the perforation. Sometimes a second purse-string suture is placed.

If omentum is available it is drawn around the tube and held by a few sutures of catgut, or an incision may be made in the omentum and the tube brought through the omentum. The omentum should then be sutured lightly to the bowel on each side of the tube. Long does not fasten the tube in position by suturing it to the bowel wall, for he thinks the suture will cut through and so increase the size of the intestinal opening, making a larger fecal fistula that will be difficult to close because of eversion of the mucosa. The tube is fixed by long strips of adhesive plaster from the tube to the skin, and the abdominal wound is lightly packed with gauze around the tube. Occasionally the loop of bowel may be anchored to the parietal peritoneum by two interrupted sutures. This, however, is not always necessary.

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# CHAPTER XVI

## INTESTINAL OBSTRUCTION

**Research in Intestinal Obstruction.**—Intestinal obstruction is always fraught with grave danger. While the mortality is not so high as it was a few decades ago it is still sufficient, even in the best hands, to demand the most careful attention. Ashhurst collected a record of 346 cases of intestinal obstruction with a mortality rate of 69.3 per cent. Guillaume, quoted by Lee and Downes, found in a record of 694 cases that there was 17.5 per cent mortality in those cases in which enterostomy alone was performed, 48.2 per cent mortality when there was simple release of the obstruction, and 24.8 per cent of the patients died when the operation consisted of relief of obstruction and enterostomy. The lowest mortality rate was in the group of cases in which enterostomy alone was done, while the next lowest was when the enterostomy was performed and relief of the obstruction was accomplished.

There has been much experimental work on intestinal obstruction in the last few decades. The cause of death after obstruction and the origin of the toxemia which apparently produces death have been debated by different observers. J. W. Draper, of New York, in many publications has held that the source of the toxemia in intestinal obstruction, especially in high obstruction, is from the mucosa of the upper intestinal tract, particularly the duodenum. According to Draper, these secretions are normally neutralized or detoxicated by the mucosa of the lower intestinal tract, which explains why high obstructions are more rapidly fatal than low obstructions. Sweet believes that the source of death is from a disturbance of pancreatic activity. Fred T. Murphy and Beth Vincent hold that the toxic substance causing the symptoms in intestinal obstruction is purely bacterial in origin. Stone, Whipple and Bernheim have reported results of experiments from which they believe that the toxic material formed in obstruction is independent of food substances or of the secretions of the stomach, liver or pancreas. When this toxic material from an obstructed loop of bowel is injected into the vein of a normal dog, it reproduces the picture of experimental obstruction. Whipple has isolated a toxin which is found not only in the intestinal contents of an obstructed loop, but in its mucosa. This toxin is not absorbed by the normal mucosa of unobstructed bowel. He is inclined to believe that the intestinal mucosa from some perversion of its function due to the obstruction is a source of the toxin.

This conclusion of Whipple, however, is not sustained by Fred T. Murphy and Barney Brooks, of Washington University, and Dragstedt, Moorhead,

and others of the University of Chicago. Dragstedt, Cannon, and Dragstedt, as a result of experimentation by themselves and their associates, believe that intestinal obstruction tends to the development of proteolytic intestinal bacteria without regard to the character of the diet, and that the intestinal secretions do not inhibit the growth of Gram-negative or proteolytic bacteria in a closed intestinal loop. They state that the toxic product is of the class of amines. The disappearance of Gram-positive bacteria in a closed intestinal loop seems to be due to the absence of carbohydrates as well as to the alkaline reaction to the intestinal secretion. When a closed isolated loop of bowel is washed with a saturated solution of tannic acid previous to closure it does not become distended, and there is no toxemia, though what contents accumulate in the loop show many living Gram-negative bacteria even months after the loop has been closed. Without this preliminary preparation a closed loop becomes distended and there is death from toxemia in a few days. Their work does not seem to support the theory of Draper that there is a normal toxic secretion from the duodenum which is neutralized or detoxicated under normal conditions by the jejunum lower down; nor the contention of Whipple that the toxic material is due to a perverted condition of the mucosa under obstruction. They are inclined to believe that "bacterial activity plus necrotic tissue, or the absorption of toxic products resulting from the action of putrefactive bacteria on necrotic tissue is the important factor in the rapid death in simple closed intestinal loops."

Some workers in experimental intestinal obstruction believe that there is a definite toxin produced in the lumen of obstructed bowel by bacterial action, and that this toxin cannot be absorbed by normal intestinal mucosa, but is absorbed by damaged mucosa. Stone's recent experiments seem to show that this theory of absorption is incorrect, and that pressure has much to do with absorption.

Werelius, of Chicago, believes that death from intestinal obstruction is due to liver insufficiency, and cites experiments to substantiate his view. He does not think that bacteria play any special rôle in causing death from obstruction, unless the bowel ruptures and peritonitis supervenes. He thinks it is significant that the diminution or absence of bile secretion is one of the first phenomena in severe intestinal obstruction, and he says that peristalsis stops before the cessation of bile secretion. The portal circulation is dependent to a large extent upon the rhythmical contraction of the peristaltic waves of the intestine. The hepatic veins have no valves, so that the absence of peristalsis and of the rhythmical contraction deprives the portal circulation of its motive power, with consequent abolition of liver function. In the discussion, Barney Brooks believes that while undoubtedly hepatic insufficiency is one of the causes of death from obstruction, it is due to intoxication from the toxic products developed in obstruction.

Davis and Stone, as a result of experiments, believe that normal intestinal tissue is not toxic when it is fresh, and when kept in conditions that prohibit bacterial growth continues nontoxic; but when it develops bacteria in vitro, toxic properties resembling those of fluid from a closed intestinal loop will

occur within eighteen hours. This seems to show that the mucosa is not the source of the toxic material.

The Dragstedts and their associates believe that the toxic material results from the action of bacteria on proteins and their split products, and that no demonstrable immunity can be developed against this material. They regard it chemically as a class of amines, while Whipple believes it is a proteose and that a degree of immunity can be secured against it. Stone says that the toxins which are the cause of death in obstruction if introduced in the normal bowel are to some extent absorbed. He thinks that after a small portion of these toxins is absorbed the result is similar to that of histamin which increases the peristalsis of the gastro-intestinal tract and in the open bowel hurries the bulk of the toxic material along so that not enough is absorbed to produce serious symptoms. In obstruction, however, where the toxic material cannot be eliminated by the movement of the bowel, the absorption is in greater quantity, and death may be caused.

In some recent experimental work which Harvey B. Stone reported before the Southern Surgical Association in December, 1924, he lays much emphasis upon the increased pressure in the intestinal lumen in obstruction as the cause of absorption of the toxic material. The principal points of his recent work are that fatal absorption may occur without distention or necrosis of the bowel wall, and that it is due to the increased pressure within the lumen of the intestine causing absorption of the toxic products that under normal conditions would not pass through the mucous membrane. He cites the fact that pressure within the bowel in intestinal obstruction is very much greater than the normal pressure, and that this may be due partly to the distention of the intestine, but more to the increased peristalsis in the presence of an obstruction. Stone reports experiments with India ink to show that India ink is not absorbed in the open lumen of the bowel, but is absorbed in intestinal obstruction. With an isolated loop of bowel suspended in salt solution at body temperature and still living, the toxic material obtained from obstructed loops does not pass through the bowel wall under ordinary pressure, but when the pressure within this isolated loop is increased the toxic material passes through into the surrounding fluid and can be identified biologically by its injection into normal animals.

Stone's conclusion as a result of these experiments is that pressure is an important factor in intestinal obstruction, and that the increased pressure found in obstruction causes absorption of toxins that would not pass through the wall of normal unobstructed intestine.

Stone has thrown much light upon this problem by demonstrating that the increased pressure in intestinal obstruction is largely responsible for the absorption of the toxic material. Much of the material that normally exists within the intestinal tract would be toxic if its absorption were forced by increased pressure, and this would account for many of the symptoms of obstruction without resorting to the hypothesis of a special toxin formed under obstructive conditions. Undoubtedly the obstruction produces a fertile field for a great multiplication of bacteria and either a large amount

of new toxin is formed under these conditions, or else there is a multiplication of the toxic products that normally exist within the intestinal tract. As Stone has said, unless this material is absorbed into the lymph or blood circulation, it cannot have effect, and the absorption is equally as important as the production of toxic material.

Very interesting and important recent research in experimental intestinal obstruction by Foster and Hausler has greatly served to clarify the somewhat confused situation resulting from the numerous divergent theories of intestinal obstruction.

Much of the work that has been done disregarded the type of obstruction, and assumed that an obstruction due to a single band of adhesions, or experimentally to a tape tied around the intestine, is essentially of the same nature as that produced by a volvulus of several feet of bowel. If an obstruction is produced without necrosis as by a simple band, Foster and Hausler maintain that death is slow and that if dehydration be prevented it does not occur for many days unless the source of obstruction produces a peritonitis. They treat as of no importance the peculiar toxin that is supposed to be developed in the obstructed loop of bowel, and appear to disregard to a great extent the usual opinion that death is more rapid from high intestinal obstruction than from low obstruction. Of course in high obstruction with frequent vomiting, there is a rapid loss of liquids, more rapid than would occur in low obstruction, and this dehydration would be an important factor in the rapidity of the fatal issue. On the other hand, in obstruction from a volvulus or from material interference with the vascular circulation of a considerable portion of the intestines, the clinical picture and the rapidity of death is quite different, according to these observers. In the first type of obstruction death is slow and may be postponed for many days if dehydration is prevented and peritonitis does not occur. In the latter type when the bowel is experimentally twisted as a volvulus and tied with a cord, death is rapid, follows within a few hours, and gives the picture of shock. There is low blood-pressure and failing circulation, apparently due to the same causes that produce shock. That these distinctions are important must be recognized, for clinically it has been noted that obstruction, as from cancer of the colon, may exist for days or even weeks without a fatal issue, whereas a volvulus or a strangulated hernia produces profound symptoms and a rapidly fatal issue unless the obstruction is relieved. Naturally, however, there is an intermediate zone between these two extremes. If the strangulation involves only a short segment of bowel there may not be a sufficient amount of the shock-producing toxic material to cause overwhelming symptoms, and at the same time an obstruction due to a band of adhesions causing a slightly twisted loop of bowel in which the circulation is impeded but not stopped may make a mixture of symptoms of the two types of obstruction.

Experimentally these two obstructive types should be differentiated. Observations drawn from simple obstruction without necrosis, should not be compared with those from obstruction due to volvulus or strangulation of large segments of bowel. That death from strangulation of the bowel when

the strangulation is limited to a few inches does not occur within a few hours is evident. In a patient of mine, a woman of seventy-two, referred to me on the fifth day after what was apparently a complete intestinal obstruction, the general condition was fairly good. The obstruction was due to complete strangulation and gangrene of a loop of bowel about 2 inches (5 cm.) long which had been imprisoned in the sac of an ischiatic hernia. Evidently, then, this was a mixed type with a minimum of shock-producing material, and a maximum of simple obstruction because the affected loop of bowel was not more than 2 inches (5 cm.) long and was so firmly imprisoned that it is doubtful if much of the toxic material could be absorbed. In an inguinal hernia, however, in which there is more of the bowel in the sac, the picture of the shock-producing type of obstruction often predominates.

It has long been noted that when doubtful loops of bowel have been returned to the abdomen after relief from strangulation, death may sometimes occur even though the bowel is not actually gangrenous. This may be due to the release of the toxic products of the strangulation to the circulation of the bowel, and their more rapid absorption after removal of the impediment to the circulation of the affected loop. Deaths from such causes are infrequent and occur only when the amount of affected bowel is extensive.

This work of Foster and Hausler is of great practical importance, and serves to show the necessity of relieving a strangulation or an obstructed circulation of the bowel as promptly as possible.

Haden and Orr in some excellent research work have called attention to the blood changes in intestinal obstruction. They found that in obstruction of the upper intestinal tract the blood shows first a rapid fall in chlorids and a rise in the $CO_2$ combining power of the blood, and soon after this there is a rise in the nonprotein and urea nitrogen of the blood. They believe that the fundamental change consists in the fall of the chlorids and that this is not due to any great extent to the loss of chlorids through the vomiting of gastric juice, but that it is related to the protein destruction. In obstruction at the ileocecal valve there is a rise in the blood nitrogen, but no change occurs in the chlorids so that there does not seem to be the same indication for treatment by chlorids as in high intestinal obstruction. They believe that as the chlorids rapidly fall in pyloric or in high intestinal obstruction, the administration of sodium chlorid intravenously is an excellent therapeutic remedy. They recommend that in the toxemia of a high obstruction sodium chlorid be given in an initial dose of one gram per kilogram of body weight, and that the chlorids in the blood be carefully watched to estimate subsequent doses, which should be administered with a view to keeping the chlorids at their normal level. Sodium chlorid solution may be administered subcutaneously or intravenously. Subcutaneously it is given in solution as high as 3 per cent, and in the vein as high as 5 per cent, but in these percentages it must be administered very slowly. It is probably best given in very sick cases by intravenous injection, making a solution of 2 or 3 per cent sodium chlorid, giving a definite amount which is to be checked by analysis of the blood and urine.

Orr thinks that the administration of sodium chlorid solution by proctoclysis is too doubtful a method to be used in serious cases, for the quantity of salt solution actually absorbed cannot be accurately estimated. Usually a daily dose is sufficient. In apparently desperate cases of high intestinal obstruction the injection of sodium chlorid in this manner affords almost immediate relief and is an exceedingly important remedy. Haden and Orr find that other chlorids cannot supplant sodium chlorid in this treatment, that ammonium chlorid, potassium chlorid and magnesium chlorid do not prevent an increase in the blood nitrogen and a fall in the chlorids, nor postpone the fatal result, while sodium chlorid is usually efficient in these respects.

**Symptoms.**—The symptoms of intestinal obstruction have already been alluded to in the preceding discussion. The two types of cases suggested by the experimental work of Foster and Hausler are often seen clinically, though sometimes the picture is an intermediate one between a simple intestinal obstruction and an obstruction due to strangulation of a large segment of bowel.

A reference to the physiology of the intestines, as discussed in Chapter III, will make many of the symptoms much more intelligible. The first symptom in acute intestinal obstruction is pain. This is usually severe, and when the obstruction is due to strangulation is intense. If it is a simple obstruction, as from the presence of a foreign body in the lumen of the bowel, or from a stricture or carcinoma in which the reduced lumen of the bowel has been plugged with fecal contents, the symptoms of pain are not so severe. Pain is from the powerful and irregular peristaltic waves and from the increased pressure in the bowel. As the pressure increases the bowel secretion seems also to increase, and the bowel becomes distended with liquid contents and with gas. If the obstruction is high, vomiting quickly occurs, because the lumen of the bowel is rapidly filled with secretion that regurgitates into the stomach. Reverse peristalsis occurs. The vomiting due to the reverse waves of peristalsis at first empties from the stomach gastric juice, mucus, and bile. If the obstruction is high and continues, the upper intestinal contents flow into the stomach and are vomited. If the obstruction is low vomiting may not begin for some hours, even for days. There are intermediate grades between high obstruction and low obstruction in which the time when vomiting occurs varies considerably. Usually, however, particularly in high obstruction, vomiting is prompt.

The pain is of a cramplike colicky nature, of somewhat intermittent type, and in a thin individual the peristalsis of the intestines can be easily observed through the abdominal wall. The temperature may be subnormal, depending upon the location and the severity of the symptoms. When the obstruction is due to strangulation the pulse soon becomes rapid and weak, the patient sweats, the face is drawn, and the patient presents the appearance of extreme illness.

In postoperative obstruction the symptoms are usually sudden. After operations for peritonitis, it is often difficult to tell whether there is actually

mechanical obstruction due to a deposit of lymph and adhesions, or whether there is a toxemia from peritonitis which has produced paresis of the intestinal wall. When there are paresis and general peritonitis the vomiting is often of material represented as dark brown or coffee-ground in appearance, due to the action of toxic products on the mucosa of the stomach and upper intestine, which often causes bleeding and the coagulated blood gives the coffee-ground appearance. In such cases there is an absence of peristalsis, with a high white cell blood count, spasm of the abdominal wall and rapid thready pulse. The difference clinically is in the peristalsis and muscle spasm, in the vomited material, in the fever, and in the leukocytosis. The characteristic blood chemistry of upper intestinal obstruction, as shown by Haden and Orr, is also an essential diagnostic point.

Postoperative intestinal obstruction to some extent usually differs from obstruction due either to strangulation or to a simple band, because it is often produced by a kink or pressure upon the bowel by lymphatic exudate following the operation, which will probably be absorbed within a few days if the contents of the bowel can be evacuated in the meantime. The site of the obstruction may be indicated by the contour of the abdomen. If the obstruction is above the middle of the small intestine, the contour will not be symmetrical—at least, not until the obstruction has become advanced and the dilated bowel has fallen into the lower part of the abdomen. At first, however, the swelling will be confined largely to the upper abdomen, and particularly to the left. When the distension from the beginning is symmetrical, obstruction may be looked for in the lower ileum or in the colon. The first symptoms are pain and vomiting. If the patient has had a general anesthetic, particularly ether, the vomiting from the anesthetic, which often occurs for the first two days, is sometimes continued into the vomiting from obstruction. If the patient vomits for longer than forty-eight hours after the operation, the possibility of obstruction should always be borne in mind. Most cases of postoperative obstruction, however, occur later when lymph has been poured out and the first effect of the anesthetic has passed off. There is no definite time for this, but when the lymphatic exudate has become firm and when peristalsis begins to be renewed after the abdominal operation, from the fourth or fifth day on, obstruction may arise.

**Treatment.**—The treatment of intestinal obstruction should be prompt, no matter whether it be a simple or a strangulated type of obstruction. Under no condition should purgatives be given. The stomach should be emptied by gastric lavage, which tends to evacuate the toxic materials regurgitated into the stomach or excreted by the stomach. Morphin to quiet peristalsis and relieve pain is indicated. In early simple obstruction when the pulse is good enemas may be tried. Turpentine stupes or moist applications to the abdomen may be helpful. When the obstruction is marked, however, no such measures are advisable. The patient should be operated upon as soon as possible, and the case dealt with according to the pathology present.

In postoperative obstruction, when the obstruction can be reasonably assigned to a definite location, an incision should be made in this region, and,

if possible, a collapsed loop of bowel found. If this is difficult, exploration with the finger and drawing out a distended loop may point the site of obstruction. For the first few days after an abdominal operation the character of the free fluid will doubtless be blood-tinged, so it may have no particular significance; but if the obstruction occurs many days after the operation when there is no occasion for the presence of a trace of blood in the abdominal cavity, blood-tinged fluid should be regarded as suspicious of strangulation and then the site of obstruction must be exposed. When the obstruction occurs within the first week or ten days after an operation, and is in the lower portion of the intestine and due to lymphatic adhesions, it is probably wise not to attempt to separate these adhesions unless they are very accessible, and over a limited area. Mere separation of these adhesions, if they are extensive, will result in the pouring out of lymph and the formation of even more extensive adhesions with a probable recurrence of the obstruction. If the obstruction has resulted in distention and has reached a point where operation is necessary, it will doubtless require something more than the mere separating of lymphatic adhesions. At any rate, it would be risky to rely solely upon this one procedure.

It is in such cases that enterostomy is of the greatest value. The site of the proposed enterostomy depends upon the location of the obstruction. In general symmetrical distention it is usually best to make an incision in the right iliac fossa which is always the proper field of exposure for intestinal obstruction when its location is unknown. The operation is usually done under local anesthesia, and the incision is muscle-splitting of the McBurney type. On opening the peritoneal cavity free fluid will be observed. In most postoperative obstructions the obstructive lesion is usually lymphatic adhesions that produce little or no change upon the intestinal circulation. If with a limited exploration gently made with the finger there is no indication of serious pathology, the nearest distended loop of bowel is brought into the wound. An enterostomy is done by an oblique method, preferably using the principle of Coffey already described. If the bowel is greatly distended and thin, the operation according to the Witzel technic may be performed. If the intestine cannot be readily delivered, a direct puncture with the cautery through an encircling purse-string suture as practised by Long is indicated. These procedures carry with them little shock. The old method of exploring the abdominal cavity thoroughly and relieving the distention by threading the bowel on a long glass or metal tube, should have no place in intestinal obstruction. The former dictum that after an operation for obstruction the bowel must always be returned collapsed has doubtless been responsible for many deaths.

The intestine can be satisfactorily emptied only by its own peristalsis. If, as a result of mechanical obstruction, this peristalsis has become completely abolished, death is inevitable; but if it is merely weak and exhausted, not completely abolished, giving exit to the contents of the distended bowel may reëstablish stronger peristalsis. Trauma, such as handling the intestine, exposure to air, and drying of the endothelium, tends to inhibit peristalsis.

When extensive operations are done and the bowel is opened and threaded over a long cannula, the chief indication, which is reëstablishment of peristalsis, is neglected, because these manipulations may completely destroy what little reserve power remains to the intestinal muscle. If, however, the bowel is handled gently and no segment exposed except that which is necessary for the enterostomy, relief of the distention will usually be accomplished by a renewal of peristalsis.

As has already been pointed out, surgical judgment plays a large part in the successful management of obstruction. If the obstruction is due to strangulation or thrombosis, it will be necessary to do an extensive operation to relieve the condition. In such cases, wherever there is distention, whether a resection has been done or not, there should be an enterostomy with a rubber catheter 6 or 8 inches (15.3 to 20.3 cm.) above the obstruction, because the trauma of the operation will greatly impair the remaining intestinal muscular power, and the easy exit of the contents afforded by the enterostomy will rest the intestinal muscle much more effectively than if it were necessary for the intestine to propel its contents along the whole tract and overcome the normal physiologic resistance of the remaining portion of the bowel.

In simple nonpostoperative obstruction the therapeutic indications must also depend upon the pathology present. In such instances if the patient's general condition is good, a delay of twelve hours in an effort to empty the bowel may be justifiable, and even a somewhat longer delay accompanied by the application of hot stupes to the abdomen, enemas, and gastric lavage, occasionally results in relief. Under no conditions, however, should purgatives be given, nor should the delay be longer than twenty-four hours even in simple obstruction. It is better to be on the safe side and do a simple enterostomy under local anesthesia a few hours after the initial symptoms of even a simple obstruction, than to wait too long when delay may be fatal. Then, too, as has been pointed out, it is not always possible to differentiate between simple obstruction and obstruction due to strangulation, and delay in the latter type of case may be fatal.

When the patient is past forty, and particularly if past sixty, and the obstruction has come on gradually, the possibility of cancer at some portion of the colon should always be considered. Of course, the first indication in obstruction is to search the hernial outlets to see that they are clear. Both inguinal canals, both femoral canals, the navel, and any abdominal scars should be carefully examined. A rectal examination should be made. If nothing indicates a definite location of the obstruction, a short incision, preferably under local anesthesia, is made over the right iliac fossa, and an enterostomy done. Later, a barium enema may be given and a radiologic examination made to determine whether there is a lesion in the colon. It is best not to give a barium or bismuth meal, because this may add to the obstruction. If the enema is readily expelled and is not retained, it would tend to show that the obstruction is not a simple one and that there may be a strangulation which seems to produce intense peristaltic contraction in the distal portion of the

intestine, preventing the retention of the enema. In a simple obstruction due to cancer, where the lumen of the bowel has become gradually narrowed, this excessive peristalsis distal to the obstruction is usually not present. If a cancer is demonstrated, no effort should be made to excise it until the symptoms of obstruction have been fully relieved, and the physical condition of the patient is satisfactory. This usually takes at least a week. The enterostomy tube should be retained for some days after the cancer has been removed, so as to give rest to the bowel while the line of union is healing.

When the type of obstruction is acute and violent, accompanied by prostration, sweating, weak pulse, and symptoms of shock, operation should be done as soon as possible. This condition may mean perforation of an abdominal viscus, strangulation, or gangrene of the bowel. The proper operative procedure can best be determined after the abdomen is opened.

In any type of obstruction the patient is often dehydrated, and this should be remedied by hypodermoclysis of salt solution. The importance of the observations of Haden and Orr in showing a great fall of chlorids in the blood after high intestinal obstruction should always be borne in mind, and the administration of sodium chlorid as has been suggested, should be prompt. Lavage of the stomach is important, and should always be done before operation, particularly if a general anesthetic is to be given. In late obstruction the patient has often received such an overwhelming dose of toxic material, whether it be material that is supposed to be formed in the bowel after a simple obstruction or whether it be the toxic products of strangulation, that a fatal issue may occur even after relief of the obstruction. In such instances relieving the obstruction may be like "shutting the stable door after the horse has gone," but the diagnosis of a moribund condition is not always accurate, and unless it is perfectly obvious that no hope can be afforded, some operative procedure for relief should be undertaken. Patients, formerly considered moribund, may, by the use of sodium chlorid and by gastric lavage, be benefited and saved, though in former days when these therapeutic remedies were not employed they invariably perished. Then, too, the shock that so often accompanies operations for intestinal obstruction may be successfully treated by transfusion of blood or by the intravenous administration of glucose solution and insulin, as already discussed.

The lymphaticostomy of Costain for late obstruction has given good experimental results in the hands of Costain, and a few clinical cases have been reported in which there seem to have been some beneficial effects. The theory is that toxic products of intestinal obstruction are absorbed to some extent through the lymphatics, and by them transported to the thoracic duct. Just how much of this material is absorbed through the lymphatics and how much directly through the blood-vessels it is difficult to say. Modern research, however, lays less emphasis upon the absorption by the lymphatics and the lacteals of the intestinal villi than was formerly believed. It is now known that some fat is absorbed by the veins and carried to the portal circulation. Murphy and Brooks have shown that some toxic products of intestinal obstruction pass through the thoracic duct. There may be cases in which a

lymphaticostomy should be done in order to relieve even a small portion of the toxic burden. The operation is easily performed under local anesthesia.

After infiltrating the tissues, an incision about 3 inches (7.7 cm.) long is made along the outer border of the lower left sternomastoid muscle. The muscle is exposed and retracted inward until the deep jugular vein appears. This vein is dissected clean and is followed down carefully to its junction with the subclavian vein. The dissection should be done as gently as possible, and the tissues identified, because the thoracic duct may be torn. The duct is usually easily recognized as it curves forward and empties into the subclavian vein. Retraction of the sternomastoid muscle and the deep jugular toward the midline brings the duct into view, its translucent walls conveying light yellowish fluid. It is tied, preferably with catgut, about a half inch (1.3 cm.) from its entrance into the subclavian vein. After packing around the duct with gauze and strips of rubber dam for drainage, the duct is split longitudinally, or may be partially divided transversely. A considerable amount of a rather light colored fluid containing some fat globules, unless the obstruction has lasted too long, is drained off. It was formerly thought that wounds of the lymphatic duct were very serious and often fatal. Costain has shown by his experiments, however, that this is not true, and that collateral circulation readily occurs with the duct on the right side which takes up the function of the main trunk on the left. But before this can take place, while the toxic material is being absorbed from the obstructed bowel, drainage of the main duct gives exit to most of the material transported from the lymphatics of the intestine.

Lymphaticostomy is so recent that it is difficult accurately to estimate its value. The favorable results reported by Costain have not, as a rule, been obtained by others. Lehman and Copher, in an experimental and clinical study of this operation, find that in dogs it seems to be of some benefit in obstruction, while it does not appear of any value in peritonitis. They think that, in their experiments with peritonitis in dogs, this operation has an unfavorable effect. However, they report one case in which lymphaticostomy was done after the development of peritonitis from appendicitis in a man. He seemed to improve somewhat for a few days after the lymphaticostomy, but eventually died of sepsis.

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# CHAPTER XVII

## SPECIAL CAUSES OF INTESTINAL OBSTRUCTION

**Gall-Stones; Tumors; Diverticula.**—As has been pointed out in the chapter on anatomy, the caliber of the bowel in the lower ileum is somewhat smaller than in the jejunum, and a large gall-stone ulcerating from the gall-bladder into the duodenum after passing through the jejunum and upper ileum may lodge in the lower ileum.

Benign tumors of the small intestine occasionally occur. They may be discovered incidentally in the course of other operations, or may produce symptoms, such as complete or partial obstruction or hemorrhage, which cause an investigation. Even when very large, a diagnosis before operation is usually exceedingly difficult. Benign tumors of the duodenum have been reported. They are adenomas, fibro-adenomas, or myomas. A myoma may arise from the muscular coat and protrude into the lumen of the bowel. Diverticula of the duodenum and upper small intestine have already been discussed. They rarely cause obstruction, but may produce gastric or intestinal symptoms because of inflammatory changes or pressure affecting peristalsis.

**Intussusception.**—Intussusception is not uncommon in infants and young children. The exact etiology has not been definitely determined. Often it is dependent upon irregular peristalsis in which waves of strong contraction overtake the relaxed portion of the bowel. It is doubtless true that many cases of intussusception, particularly in older children and adults, are caused by tumors. Stephen H. Watts, in 1911, reported two cases of intussusception in an adult, one of them apparently due to multiple adenomas of the ileum, and the other to a sarcoma in the cecum. A. M. Willis has reported three cases in which a tumor was found at the apex of the intussusception. It seems probable that a careful examination of the tissues involved in intussusception will disclose a much larger proportion of benign tumors acting as a cause of this affection than has been heretofore suspected. This etiologic relation is readily understood. The tumor grows into the lumen of the bowel, constitutes a partial obstruction, and so excites more powerful peristaltic waves in the proximal (oral) portion of the bowel. These waves shove down on the intestinal contents which, in passing, make traction on the tumor and invaginate the bowel wall. After the intussusception is once begun it is easily seen how it may be continued by the further pressure of peristalsis excited by the obstruction. After the intussusception begins it may be continued without regard to the causative tumor, and though the tumor is often found at the apex, it may be in other portions of the intussusception even when it served originally to produce the invagination. A careful examination of all cases of intussusception, even when a tumor is not obvious at the

apex, should be made in order to determine the incidence of benign tumors in intussusception.

The symptoms of intussusception are those of strangulative obstruction. They usually occur, as has been said, in infants and young children. The baby cries out with pain and has at first many mucous stools, frequently tinged with blood. Vomiting is an early symptom and often a mass can be felt in the right iliac fossa. In extreme intussusceptions which involve much of the colon, the tip of the intussusception can sometimes be felt by rectal examination. When strangulation is marked the symptoms are more severe, even if a relatively small portion of the bowel is involved, than with a more extensive intussusception whose circulation is less impaired. Doubtless, too, intussusceptions may sometimes automatically reduce themselves, and thus the symptoms may suddenly disappear. It is not uncommon to find in young animals that are killed a series of intussusceptions, due to an agonal variety of peristalsis.

The treatment of intussusception is that of obstruction. If the circulation of the bowel is comparatively unimpaired and reduction is easy, reduction should, of course, be done. In such instances it will be advisable to reinforce the enlarged and contracted portions of the intestine by suturing along its walls, where the apex of the intussusception was, a portion of the omentum, which will act somewhat as a splint and protect the bowel from being telescoped into the dilated lower segment. It would also be possible to lessen the caliber of the dilated portion by slightly infolding a part of its wall. If the patient's condition will admit, some such procedure would seem wise because of the not infrequent recurrences after a simple reduction. If a tumor can be palpated and appears to be pedunculated, it is removed by opening the intestine and tying the pedicle. If it has a sessile pedicle, a resection with end-to-end union is indicated. If the intussusception is extensive and involves, as it usually does, the cecum, and cannot readily be reduced, the entire affected segment of the intestine should be resected. The technic is that of resection of the lower ileum and cecum, using the Kerr method and avoiding infecting the surrounding tissue with the intestinal contents. In an infant it is probably not necessary to do an enterostomy after a resection for intussusception unless there is a very marked dilatation of the small bowel. The activity of the peristalsis and the rapid recovery in infants and children would make the indications for enterostomy much less urgent than when a resection of the cecum is done in an adult, when an enterostomy with a catheter, as has been described, is always advisable.

**Strangulation; Mesenteric Thrombosis; Tuberculosis.**—Circulatory disturbances of the small bowel are often caused by strangulated hernia. The symptoms are those of acute strangulated obstruction which have already been described in the previous chapter. The diagnosis is usually obvious because the hernia is the source of pain and presents swelling and tenderness. In rare instances, however, when a hernia is reduced the neck of the sac may be pushed in with it and strangulation is continued. Such possibilities must be borne in mind. Obstruction also occurs from a hernia into one of the perito-

neal fossæ, as the paraduodenal fossa and the fossæ around the cecum and the ileocecal valve. Congenital bands and anomalies may be the cause of strangulation.

A volvulus may occur from adhesions, trauma, or some anatomical anomaly. The treatment is the general treatment of strangulated obstruction. If there is a volvulus it should not only be untwisted, but if the circulation is greatly impaired it would probably be safer to resect than to trust a doubtful return of the circulation. All of this depends, however, upon the extent of the bowel involved, and upon the condition of the circulation.

If the segment of strangulated bowel is small and omentum is available, omentum may be sutured lightly over this bowel with the purpose of affording additional circulation to the injured intestinal segment through the adherent omentum. It has been demonstrated experimentally in dogs that the mesenteric attachment of the small intestine can be severed for about 4 inches (10.2 cm.) and the vitality of the bowel be maintained in about half of the experiments by wrapping around it the omentum, which quickly becomes adherent. If the separation of the mesentery is for more than 4 inches (10.2 cm.), gangrene almost always supervenes. While this method should not, of course, be used in bowel that is obviously gangrenous, it may afford some protection when the condition of the intestinal circulation is doubtful, and the welfare of the patient demands as simple a procedure as possible. In such cases, in addition to suturing the omentum, a quick enterostomy with a tube should be done, not only to drain the intestinal contents above the affected bowel, but to reduce the distention with its evil effects of forcing into the circulation toxic products that might not otherwise be absorbed.

In mesenteric thrombosis or mesenteric vascular occlusion, the lumen of the superior mesenteric artery or of some of its branches becomes occluded. This condition is not one of extreme rarity, though it is uncommon. More than 500 cases have been reported, and these probably represent a small portion of the actual number. Conditions which would produce thrombosis elsewhere, such as heart disease, phlebitis, or intravascular clotting from sepsis, may cause the thrombus or embolus. A prominent source of thrombosis is puerpural sepsis. This acts not only as a cause of thrombus formation, but in pregnancy the large venous sinuses in the uterus may empty their clots into veins and so become a source of embolism of the mesenteric arteries. Thrombosis may also occur from a strangulated hernia or a volvulus, or any condition that produces an interference with the circulation. The branches of the superior mesenteric are usually involved. Rarely, the inferior mesenteric is affected.

The symptoms are somewhat different from those after ordinary strangulation, because the first stage is not constriction of the lumen of the bowel, as after strangulation from hernia or volvulus, but interference with the blood supply, which is usually sudden and occurs with the intestinal tract otherwise normal. Consequently, the first feature is intense pain which may be of ischemic origin. The pain occurs with the abdomen not distended and

without the usual initial symptoms of obstruction. Later, there may be vomiting and sometimes bloody stools. As the nutrition of the bowel has been impaired and peristalsis is absent over the impaired segment there will be, as a subsequent stage, obstruction. The fact that in such cases the intestinal obstruction is not primary serves to some extent in differentiating the condition.

The symptoms come on suddenly, and there is intense pain followed by nausea, vomiting, and shock. The pulse usually increases rapidly. Peristalsis for the time appears to be inhibited. Stuart McGuire has reported two cases with the typical symptoms of sudden, agonizing pain, with shock. Both of them recovered after operation. John H. Blackburn, of Kentucky, in an analysis of a case of his own, shows that in practically every patient the pain is described as cramplike and agonizing. It may be largely confined to any portion of the abdomen, or general over the whole abdomen. It may be localized at first, becoming general later on, though this is uncommon. Tenderness is usually present. Often a mass can be indefinitely outlined. Later there is distention. Muscular rigidity is present in some cases, and absent in others. In the earlier stages the temperature is usually normal or subnormal, but later may rise if the progress of the disease is not too rapid. Later still, there may be collapse with the temperature subnormal. The leukocyte count is usually elevated.

In those in whom an embolism or thrombosis may be expected, as after a recent pregnancy, or with a vegetative endocarditis, arteriosclerosis, or degeneration of the arteries, sudden abdominal pain without distention and without marked muscle spasm should suggest mesenteric embolism.

Operation should be done as soon as possible. Extensive segments of the bowel may be successfully removed. The important point is to be sure that the stumps of the bowel which are to be united are satisfactorily supplied with blood. Flint has collected a series of 58 cases from the literature in which, for various causes, 4 feet (122 cm.) or more of the small bowel have been removed. Forty-nine of these cases recovered from the operation. Apparently the greatest length of bowel that has been successfully resected was a little over 12 feet (366 cm.). This case was reported by Brenner. The patient died about two and a half years later of inanition. Reasonably good health and life seem possible in man after removing as much as one-third of the total length of the intestinal tract.

Tuberculosis of the small bowel may produce obstruction, particularly the hypertrophic form which usually originates at the cecum and later involves the lower ileum. Ulceration may occur in the lower ileum with perforation. This was not uncommon when typhoid fever was more prevalent and the symptoms were usually those of pain followed by rather profound shock with rapidly developing peritonitis. Tubercular ulcers of the lower ileum occur and may perforate. The treatment of perforation is immediate operation. Often a single perforation can be closed by sutures. If there are multiple perforations it would probably be better to resect the involved segment of bowel. In such cases the gravity of the procedure is great and the prognosis bad, but it may offer the only possible chance for the patient.

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